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POTATO SPRAYING AND DUSTING EXPERIMENTS 1921 TO 1925.

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BULLETIN 334

POTATO SPRAYING AND DUSTING EXPERIMENTS 1921 TO 1925.[1]

DONALD FOLSOM AND REINER BONDE[2]

SUMMARY

(1) The records available for 1892 to 1921 indicated that spraying with Bordeaux mixture would increase the yield about a fifth on the average in Maine.

(2) In 1921 aphids (plantlice) were reduced by excessive amounts of nicotine-sulphate (Black-leaf 40) added to Bordeaux mixture, but the aphids left on the lower leaves and the cost of the treatment made this method of control impractical. Heavy vine growth interfered with aphid spraying. A drag-bar, a 12-nozzle boom (for 4 rows), and a commercial oil emulsion were tested, with the results unsatisfactory.

(3) In 1922 tests with two varieties on three farms in four fields showed copper-lime dust to be about as effective as Bordeaux mixture in controlling late blight and in increasing the yield, though it did not control early blight and flea beetles as well. No effect of drifting dust was apparent.

(4) In 1923 there was practically no injury from late blight, early blight, and flea beetles, even on the untreated control plots, and the yield was depressed somewhat by dusting and still more by spraying.

(5) In 1924 there were no flea beetles and frost killed the vines before the untreated controls had been entirely killed by early blight and late blight. Late blight was controlled perfectly by spraying and nearly as well by dusting. Early blight was controlled well by dusting and better by spraying. The

[1]See Literature cited at the end of this bulletin for a list of reports of previous experiments. A recent publication giving general practical recommendations is the Maine Agricultural College Extension Circular 85, Bordeaux mixture, by A. K. Gardner, December, 1923.

[2]The junior writer is responsible for the spray applications in 1924 and 1925 and for part of the corresponding field and storage notes.

yield was reduced slightly by dusting and increased slightly by spraying. Rot in lots stored in barrels was negligible.

(6) In 1925 flea beetle injury was negligible. Early blight was about as in 1924. Late blight was developing by August 21 but was checked thereafter by the weather conditions. A trace of rot was found at digging. The yield was increased about the same by spraying and dusting. Storage tests gave 1 to 3 per cent rot in bins and less in barrels.

(7) In tests made in 9 seasons (1916 to 1919, 1921 to 1925) with Green Mountains, on or near Aroostook Farm, 121 barrels (332 bushels) was the average yield rate of unsprayed plots in healthy crop at digging. In these tests the increase by spraying was such as to average 17 bushels a year, or about 5 per cent. According to calculations given, such an increase was enough to justify the expense of spraying in 1926. Including figures for 1920 by assuming this year to be like 1917, we get 10-year averages of 117 barrels (321 bushels) and an increase of 21 bushels or about 6 per cent.

(8) Although Bordeaux spraying in many regions is usually decidedly profitable, it is not always so. In Aroostook County there are a number of factors which tend generally to reduce the profits. Therefore more economical methods of spraying are desirable at least on some farms.

(9) Many conditions can make the tests on one farm unrepresentative of the locality or region as a whole. Methods are suggested for a grower to try if in doubt regarding the desirability of continuing his present plan of spraying.

(10) The effects of using a vine protector were not great enough to appear significant under the conditions of field variation obtaining in the tests.

(11) Alleged advantages of dusting are listed. Reports from other regions generally give higher cost for dusting, due to the cost of factory-mixed materials, and lower yield increases, due to less control of insects and diseases, as compared with spraying. Conditions of these tests differ widely aside from those of region and season. Costs based on Aroostook County tests, with equivalent conditions as to the amount of metallic copper applied, are about half again as great for dusting as for spraying. Leaf samplings taken in Aroostook County in 1923 show upon analysis that the copper in Bordeaux mixture ad-

heres better than that in copper-lime dust. The timeliness and agreeableness of dusting may be overestimated as advantages.

(12) The use of 5-50 copper sulphate solution to hasten maturing was an entire waste of effort and materials.

GENERAL REASONS FOR SPRAYING POTATOES

Much has been learned and written about potato diseases and pests and about their control by spraying. The present status of the general problem is well described in Farmers' Bulletin 1349 (24)[3]. "This bulletin tells how to control the Colorado potato beetle and late-blight (the two worst enemies of the potato), blister beetles, flea-beetles, cutworms and other caterpillars, leaf-hoppers, aphids or plant-lice, and early-blight and other foliage diseases.

"For most of these insects and for the diseases discussed in this bulletin, spraying with Bordeaux mixture and lead arsenate is recommended, but for aphids or plant-lice, contact sprays, such as nicotine sulphate and emulsions, are the best. For blight, Bordeaux mixture is an efficient means of control." (24, p. ii.) "Spraying is very profitable in districts where potato insects and leaf diseases annually take a big toll. The most successful growers in these districts, who wish to be insured against loss, practice thorough and consistent spraying, knowing that there will be large returns on their investment." (24, p. 19.)

Aside from giving control of diseases and insects, spraying with certain copper-containing materials is often said to give a beneficial stimulation to potatoes. Such stimulation has been claimed as being profitable in the absence of diseases and pests, and presumably would operate also in their presence though in the latter circumstances without the possibility of proof. However, this so-called copper stimulation probably has often been credited with benefits derived from the reduction of hopperburn, which until recently was confused with physiological tipburn.

Another reason for spraying that is of very minor importance is the occasional desire to kill the "tops" before they would die from natural causes. This problem is met only in a region with short growing seasons, and is met there only in a season with the

[3]Reference is made by number to "Literature cited," p. 280.

autumnal killing frosts occurring later than usual. The advantage sought is to hasten the maturing of the crop so as to reduce the danger of bruising by early digging of immature stock, or of frost injury consequent to late digging.

It may be pointed out here that several causes of spraying not being done as much as is advocated by the authorities, are a lack of knowledge of the actual causes of certain diseases and types of insect injury, due to the obscurity of these causes; an inherent tendency to gamble with the hope of striking a year of less gain from spraying; a lack of preparation; a dislike of the work due to its unpleasantness; and a lack of convincing proof of an average profit from spraying. Preparation requires a number of suitable containers and suitable lime, and unpleasantness is in part mental due to the necessity for following directions in a certain way.

STANDARD METHODS OF SPRAYING POTATOES

According to the Farmers' Bulletin previously referred to, "all commercial growers should provide themselves with the most effective traction sprayer they can secure. In these the pump is operated by a chain or gear drive from the wheels. It pays to get the best, as a high pressure of 120 to 150 pounds is needed for effective work. Gasoline engine power outfits do still better work and are suitable for large growers who desire a sprayer covering four or more rows with three nozzles per row and maintaining at least 200 pounds pressure. A good nozzle is one of the most important parts of a spray outfit. The cyclone or eddy chamber type, of which the Vermorel is an example, is the best. The spray produced should be in the form of a fine mist covering every part of the plant." (24, p. 20.)

Potato spraying standards recommended in Maine (2, 37) are like those just quoted from Farmers' Bulletin 1349. These standards have been followed in normal practice on the Maine Agricultural Experiment Station farms, with satisfactory control of diseases and pests except for some injury to the emerging plants by flea beetles before the first application of spray materials. We are not so familiar with the normal practice of the potato growers of the State, but in some cases at least it is similar to that of the Station farms.

REASONS FOR CONDUCTING POTATO SPRAYING AND DUSTING EXPERIMENTS IN MAINE

The chief reason for carrying on potato spraying and dusting experiments in all potato regions at present is to test possible substitutes for standard methods. New materials, new equipment, and new methods of using materials and equipment, are frequently suggested as offering greater net profits either through greater effectiveness against diseases and pests at the same cost, or through lower cost with the same effectiveness. Another advantage suggested for a number of prepared materials is greater convenience, but this largely resolves itself into greater effectiveness through fewer errors occurring during application, or into a lowering of the cost through reducing the amount of labor needed. Convenience for its own sake alone is often compensated by later inconvenience due to uncontrolled diseases and pests and is not to be given much credit here.

It should also be pointed out that some experiments are needed in any given potato region to determine whether general standard methods need modification in the region concerned. Diseases and pests are not the same in different regions, either in kind or amount. Yields and other factors in production influence the profitableness of the same method so that it may be more valuable in one region than in another. These various conditions may change as a region is developed in regard to potato growing.

It therefore has seemed necessary in the past in Maine, as elsewhere, to conduct experiments in spraying and dusting potatoes. The results of the previously published tests in Maine will be briefly reviewed before proceeding to a description of the recent tests that are published for the first time in this bulletin.

TESTS IN MAINE UP TO 1921

The first tests of Bordeaux mixture in Maine were made in 1892 (8). However, not until 1902 was a particularly bad attack of late blight one of the conditions where tests were being made "in the great potato growing region of this State" (93, p. 203). Further, "ready made Bordeaux mixtures were not used in experiments in the Station this year [1902]. In former years they

gave fairly satisfactory results. Some users in 1902 are not as well satisfied as though they had used the regular home made mixture. This can probably be explained by the fact that if they had used the ready made goods in accordance with directions which come with them, they were only about one-half the strength of the home-made goods." (93, p, 204). It therefore appears that up to 1902, inclusive, only Bordeaux mixture had been severely tested against blight in a scientific experiment in Aroostook County, and this material only once.

In 1903 a test of prepared (hydrated) lime as against lump (quick or unslaked) lime showed it to be an effective substitute that had greater convenience (95, p. 189-192). In 1904 and 1905 dry Bordeaux was tested, applied as a dust to dry foliage with no check plot available. In 1907 a similar test was made (68, p. 293-294.) This year late blight and rot were bad and the best dust gave less yield than the average of several standard wet-sprayed plots. In addition, commercial prepared Bordeaux mixtures were given their first hard test, and the two kinds tried were less effective than the best dust, referred to. Another proprietary compound in 1908 failed to control early blight, with a resulting lower yield than was given by standard Bordeaux mixture (98.)

No further experimental tests were made until in 1916. In this year and in 1917, 1918, 1919, and 1921, results were obtained by Cook (28, 29) who at the same time made comparative tests in other regions. He reviewed previous publications on the problem in question. His most important conclusions with some comments are indicated as follows:

In 1916 in the Green Mountain variety in northern Maine near Aroostook Farm at Presque Isle, on August 24 the vines in the plots sprayed with 5-5-50 Bordeaux were green, while those in the check plots had died. In spite of this difference[4] in length of growing season, the 8 Bordeaux plots yielded only 2 per cent more on the average than did the 8 check plots. This small difference has little significance considering that the yields varied from 1026 to 1386 pounds per 800 feet of row for the Bordeaux plots, and from 957 to 1335 pounds for the check plots. The lack of significant increase in yield with longer life of the vines is

[4]Meteorological records show that the first killing frost of the autumn of 1916 occurred on September 11.

probably because "the vines of the check plats were not injured by driving through the plats, a factor of some importance in view of the fact that the spray cart was driven twice through some of the sprayed and four times through others when each spray was applied." (28, p. 10.) Although the estimated percentage of leaves affected with late blight was 7 to 60 per cent for the checks while only 2 to 7 per cent for the Bordeaux plots, "no rotten tubers were found on any of the plots." This probably was due to the early death of the vines occurring chiefly from early blight, this disease being on 41 to 78 per cent of the leaves even in the Bordeaux plots, and on still more, and probably in a more severe extent, in the checks.

In 1917 in the Green Mountain variety on Aroostook Farm, late blight was bad, being on 37 to 45 per cent of the leaves in the Bordeaux plots where it also caused 8 to 17 per cent of the tubers to rot by digging time. The yield was 30 to 40 per cent greater in the sprayed plots than in the checks, but the checks showed no more rot, probably because of the early death of the vines in the checks. (28, p. 10-12.)

In 1918 in the same variety and on the same farm, a disease-free 5-5-50 Bordeaux plot outyielded an adjoining check plot by only 3 per cent though the latter had 33 per cent of the leaves affected with late blight and the former had only 0.5 per cent. "The dry season and the fact that the vines were killed by frost on September 9 tended to reduce the increased yields which are usually obtained from sprayed plats." (28, p. 13.)

In 1919 in the same variety and on the same farm, with traces of late blight observed from September 1 to September 12 when a killing frost occurred, with Bordeaux used the yield was 6 per cent greater than with no spray. (29, table 3.)

In 1921 in the same variety and on the same farm, with Bordeaux the yield was 5 per cent greater than with no spray. On the same farm but in the Irish Cobbler variety the yield was essentially the same,—actually a little in favor of the check. On another farm in the Green Mountain variety the average yield of 4 Bordeaux plots was 16 per cent greater than that of 4 check plots, with the best check outyielding the poorest Bordeaux plot. (29, table 6.)

Cook also compared other copper spray materials with Bordeaux mixture. He states that "the amount of copper sulphate

essential for the control of late blight on potatoes in Maine may be reduced 44 per cent by the use of Pickering sprays. The amount of lime required is reduced also and all grit removed from the spray, while at the same time the wear and tear on spray machinery is greatly diminished. These results were obtained in Maine where the principal potato trouble is late blight. It is impossible to state what the efficacy of Pickering sprays on potatoes would be in sections where other troubles predominate." (28, p. 22.) "The various Pickering and Bordeaux sprays tested adhered equally well to the potato leaves." (28, p. 21.) "The copper of the Burgundy mixture (sal-soda Bordeaux) did not adhere as well as the copper of standard Bordeaux, for the reason that all of the copper had not been precipitated by the sal soda." (28, p. 21.)

"Bordeaux and other sprays containing copper are usually applied to the potato to control the late blight. In some States such a spray is applied as a repellent to the flea beetle and the potato leafhopper, thereby reducing the injury to the foliage from these two insect pests and at the same time lessening tip burn and hopperburn." (29, p. 23.) "There is a possibility that the protective effect of Bordeaux is the only effect produced, but copper salts have such a pronounced effect on all living tissue that a stimulation is generally suspected and even accepted by many investigators in this field." (29, p. 22.) "At Arlington Experimental Farm [in Virginia,] some of the increased yield of tubers from copper-sprayed potato plants was undoubtedly due to the action of the copper sprays in controlling potato leafhoppers and thereby reducing hopperburn. It is difficult to explain it all on the basis of protective action alone." (29, p. 21.) "The writer has shown that tubers contain only traces of copper, while the roots, stems, and leaves of potato plants contain appreciable quantities." (29, p. 20.) "These results suggest the possibility that a certain proportion of copper in a spray gives the maximum stimulating effect in this locality and that a spray containing a greater proportion of copper may have a toxic rather than a stimulating effect." (29, p. 18.)

Thus Cook, believing in copper spraying as a stimulant to potatoes, in 5 years' tests in Aroostook County got over 6 per cent increase in yield in only one year. In two years he got an increase that was decidedly disappointing in comparison with expectations based on the appearance of the foliage. He concluded that the

TABLE 1.

Effects on disease[1] of spraying in Maine previous to 1922.

Year	Publication[2]	Regional conditions		Check test plots		Yields of other test plots[3]		
		Diseases[1] and yield	Effects of spraying	Diseases[1]	Yield	Bordeaux mixture	Dust	Miscellaneous
					Bus. an acre	Bus. an acre	Bus. an acre	Bus. an acre
1886	(7)			None				
1887	(5)		No spraying	None	289[4]			
1888	(5)		Do	None	313[5]			
1889	(9)	Very bad	Do[6]					
	(58)	Bad on late varieties outside of Aroostook County	Do		738[7]			
1890	(1)				344[8]			
1891	(10)			"Rust"[9] by August 12, greatly reducing yield	190[8]			
	(10)			Yield cut in two by rot	159[8]			
1892	(8)	Variable	No spraying			?[10]		
1893	(3)				328[11]			
1894								
1895	(89)			10% rot		+⅓		
	(4)	No great damage						
1896	(96)			None	275[12]			
1897	(42)	Much damage	Decisive					
	(96)			"Early rust"[9]	138[12]			
1898	(44)	Variable, less than in 1897						
	(96)[13]			"Rust"[9]		330[14]		
	(96)[15]			Blight[16]		201[17]		
1899	(43)	Not as bad as usual	Helpful					
1900	(90)			75-100% early death from blight; 15% rot at digging	209[18]	+105(50%)		
1901	(93)	Some blight and rot	One or two applications effective					
1902	(93)	Blight bad	Two applications useless			387[19]		
1903	(94, 95)			Blight; 30 to 50% rot at digging, more in storag		+⅓ to ½		

Effects on disease[1] of spraying in Maine previous to 1922.—Continued.

Year	Publication[2]	Regional conditions		Check test plots		Yields of other test plots[3]		
		Diseases[1] and yield	Effects of spraying	Diseases[1]	Yield	Bordeaux mixture	Dust	Miscellaneous
					Bus. an acre	Bus. an acre	Bus. an acre	Bus. an acre
1904[20]	(89)							
1905	(97)	Little blight				382	374[21]	
1906	(68)	Early blight destructive; late blight absent	Helpful			275-281[30]	275-281[30]	
1907	(68, 99)	Little early blight; late blight severe; much rot	Effective only when very thorough	Little early blight; early death from late blight; 46% rot at digging	207[22]	+93(45%)[23]	—15(7%) to +64(31%)[24]	+32(15%) to +41(20%)[25]
1908	(67)	Early blight bad; little late blight	Helpful					
	(98)	Do				343[18]		300[26]
1909	(69)	Late blight and rot bad	Usually useless					
1910	P.P.D.[27]	Little early and late blight						
1911	P.P.D.[27]	Do						
1912	P.P.D.[27]	Do						
1913	P.P.D.[27]	Not bad						
	(66)			Total destruction of foliage by late blight where infected seed was planted				
1914	P.P.D.[27]	Not bad						
	(66)			Heavy loss of foliage by late blight where infected seed was planted				
1915	P.P.D.[27]	Early blight slight; late blight slight in north, 50-75% in south						
1916	P.P.D.[27]	Do						
	(28)			Early blight; late blight, no rot		+2%		P'g[28]
1917	(59)	Nearly 50% loss from blight	Often not effective					

Effects on disease[1] *of spraying in Maine previous to 1922*—Concluded.

Year	Publication[2]	Regional conditions		Check test plots		Yields of other test plots[3]		
		Diseases[1] and yield	Effects of spraying	Diseases[1]	Yield	Bordeaux mixture	Dust	Miscellaneous
					Bus. an acre	Bus. an acre	Bus. an acre	Bus. an acre
	(28)			Late blight and rot		+30 to 40%		P'g[28]
	(86)			95% of foliage destroyed by late blight				
1918	(28)			Late blight		+4%		P'g[28]
	(86)			10% of foliage destroyed by late blight				
	P.P.D.[27]	Late blight bad near coast						
1919	(29)			Trace late blight late	305	+17(6%)		
	(86)			Blight negligible				
1920	(60)	Late blight bad						
	(86)			75% of foliage destroyed by late blight				
1921	(29)			No late blight	319-411	+0 to 18%[29]		
	(86)			Blight negligible				

[1]Such as are directly affected by spraying, e.g., early blight and late blight and the rots that they cause.
[2]Numbers in parentheses refer to Literature cited, at end of bulletin.
[3]When possible, indicated as decrease (—) or increase (+) comparing with check plot.
[4]Triumph variety, selected from many used in a variety test.
[5]Delaware variety, selected from many used in a variety test.
[6]Copper fungicides recommended on basis of 1889 trials elsewhere.
[7]Prize acre in Aroostook County.
[8]Fertilizer plot in Aroostook County.
[9]"Rust" probably refers chiefly to late blight, but early blight was not distinguished from late blight even by scientists until in 1892.
[10]Tops longer lived but yield not increased in proportion expected.
[11]Early Rose variety, selected from several used in a cultivation experiment.
[12]Approximately.
[13]Nos. 3038-3041.
[14]Sprayed 3 times. Rot bad, beginning before any of the leaves were killed.
[15]Nos. 3050-3051.
[16]Killed sprayed plots finally.
[17]Sprayed 3 times. Variety White Elephant.
[18]Average of two plots.
[19]Average of 12 plots sprayed 5 times.
[20]Date given in (97, p. 34).
[21]Including 4% rot.
[22]Including 46% rot at digging.
[23]Average of 6 plots sprayed 6 times. Includes 7% rot at digging.
[24]Range of 4 plots. Includes 21 to 36% rot at digging. More rot in storage.
[25]See text, p. 210.
[26]See text, p. 210.
[27]From unpublished records in the Office of the Plant Pathology Dept., Maine Agr. Expt. Sta.
[28]See text, p. 211, on Pickering sprays.
[29]See text, p. 211.
[30]Sprayed and dusted plots not distinguished in record.

amount of copper applied in this region could be reduced with safety as far as control of diseases is concerned, and should be reduced if the greatest stimulation is desired.

Further, Cook points out that the use of Bordeaux gave an average gain of 60 bushels an acre for a 10-year period in New York, and an average gain of 105 bushels for a 20-year period in Vermont. Also, that Lutman (of Vermont) believes Bordeaux to be nonbeneficial in the absence of tipburn, flea beetles, early blight, and late blight, and that Lint finds that "increased yield of tubers does not consistently result from the application of Bordeaux to potato plants in New Jersey." (29, p. 3, 13.)

THE STATUS OF THE PROBLEM IN MAINE BY 1922

The significant results of the tests that have been made in Maine and that have been reviewed briefly in the preceding section of this bulletin, together with seasonal reports on diseases and spraying, are given in Table 1. Records for one or more parts of Maine are given for the years 1886 to 1921, inclusive, excepting 1894 and 1899. This is for 34 seasons in a period of 36 years. Diseases were bad in unsprayed fields in at least part of Maine in 1889, 1891, 1897, 1900, 1902, 1903, 1907, 1909, 1915, 1916, 1917, and 1920. In these 12 years the losses probably averaged about 40 per cent or less, which spread out over the whole series of 34 years would average 14 per cent a year. The effects of diseases were less, but were still marked, in 1892, 1895, 1898, 1899, 1906, and 1908. Estimating that the losses in these 6 years averaged about 20 per cent, we get an average of 3½ per cent added for the 34-year series.

This gives a total average loss of 17½ per cent for the 34 years. If instead of estimating the loss compared with an ideal healthy condition, we calculate the gain over the actual yield that control of the diseases would have given, we get about 20 per cent average gain. This latter method of comparison would be necessary in order to consider whether net profits were to be expected by effective spraying. In brief, spraying to break even would only have had to cost what would be added to the value of the crop by a 20 per cent increase in yield. This general conclusion does not pretend to a high degree of accuracy. In some years diseases were

not bad in Aroostook County and in other years much spraying did not control diseases when done, both of which facts reduce the expectation of profits from spraying. On the other hand, the other 17 years of which no mention have been made, in which there was little loss noted from disease, may possibly be represented fairly by 1916, 1918, 1919, and 1921. In these four years experimental tests usually showed some increase in yield from spraying.

Altogether it would seem that by 1922 the available facts would justify attempting effective spraying against early blight and late blight, and incidentally against flea beetles and leafhoppers, if the expected cost would be less than the increase in net returns expected from a fifth larger crop. Such a suggested comparison of cost and gain was not made in 1922 inasmuch as commercial conditions were still abnormal and unstable, as is well known. It will be made further on in this bulletin for Aroostook Farm on the basis of tests made there, including those made in the years 1922 to 1925 inclusive.

Not only were commercial conditions unstable in 1922, but other uncertainties made it appear wise to continue experimental tests on Aroostook Farm. Dusting was being considered as a substitute for spraying with Bordeaux mixture. Also, the study of degeneration diseases had indicated a possible advantage from controlling certain insects that could transmit these diseases. As will be shown in the next section of this bulletin, in 1921 the control of aphids, which are insects that can transmit degeneration diseases, was shown to be impractical in Aroostook County by means of spraying. Their control by dusting, however, seemed more hopeful according to results reported from elsewhere. (23, 79.) It was thought therefore that tests of the value of dusting against diseases and insects producing direct injury would not only answer a strong demand from Aroostook growers for information as to that question, but would also show whether dusting was worth testing further in regard to its value against such insects as might be shown to be transmitting agents of degeneration diseases.

APHID-SPRAYING EXPERIMENTS IN 1921 WITH MODIFICATIONS OF BORDEAUX MIXTURE[5]

In 1921, experimental tests were made on Aroostook Farm with both nicotine and oil modifications of Bordeaux mixture, as to their value in this region against aphids (plant-lice). These insects were the only ones then demonstrated to be transmitting agents of certain degeneration diseases (32, 33). The tests were made on a 1½ acre Green Mountain seed plot that was rogued for degeneration diseases. There were 19 four-row spray plots. A traction sprayer was used with three modifications of the boom. The treatments planned for the various plots are given in Table 2.

TABLE 2.

Spraying treatments planned for the 19 plots in 1921.

Plot No.	Boom	Modification of Bordeaux Mixture
1	12-nozzle L. B. Smith type (See Fig. 26, above)	None (control)
2	Ditto	Nicotine sulphate[1] 1/800[2]
3	Ditto	" " 1/400[3]
4	Ditto	" " 1/200[4]
5	Ditto	Kerosene emulsion[5] 1/50
6	Ditto	" " 1/25
7	8-nozzle boom and drag-bar[6] (See Fig. 26, below)	None (control)
8	Ditto	Nicotine sulphate 1/800
9	Ditto	" " 1/400
10	Ditto	" " 1/200
11	Ditto	Kerosene emulsion 1/50
12	Ditto	" " 1/25
13	8 nozzle boom	None (control)
14	Ditto	Nicotine sulphate 1/800
15	Ditto	" " 1/400
16	Ditto	" " 1/200
17	Ditto	Kerosene emulsion 1/50
18	Ditto	" " 1/25
19	Ditto	None (control)

[1]In the form of "Black-leaf 40."
[2]Or at the rate of ½ pint to 50 gals.
[3]Or at the rate of 1 pint to 50 gals.
[4]Or at the rate of 2 pints to 50 gals.
[5]In the form of a commercial preparation said to be 70 per cent kerosene.
[6]The drag-bar was not used for the first application when the plants were small.

The season was unusually early as to the development of potato plants. Applications were made on June 23, July 1, July 12, and July 21-22, with the insecticidal modifications. The oil

[5]Dr. Edith M. Patch, the Station Entomologist, helped with the plans and with colonizing and counting of the aphids in the experimental plots.

modification prevented an even spreading of the liquid film over the leaves, as shown in Figs. 27 and 28. The large size of the plants early made it impossible to make a thorough application on all the upper leaves with a single upper nozzle, in the 12-nozzle boom with 3 nozzles to a row (Fig. 26, above). The density of the foliage (Fig. 29) greatly reduced the effectiveness of the two lower nozzles of this boom. Drop-nozzle booms have been unsatisfactory in New Hampshire also (18, p. 2). The drag-bar (Fig. 26, above) made the coating incomplete because of the bending and switching produced during application.

Having thus eliminated the oil modification, the 12-nozzle boom, and the drag-bar from serious consideration by the last of July, the next application was made on July 30 when an excessive amount of nicotine was tested on plots 8, 9, and 10. Here two applications were made, one with two nozzles above and the other a few minutes afterward with two nozzles below, in the latter case using the 12-nozzle boom with the 4 upper nozzles plugged. The pressure was about 180 pounds. The effect of this excessive application was determined by counting the aphids present on July 31. Of the aphids recorded about 98 per cent were of the species (*Macrosiphum solanifolii* Ashmead) that migrates from rose bushes to potatoes and other plants in the spring (see 74, p. 13). The counts on July 31 were not made on entire plants, as had been done previously, because each plant now bore about 100 leaves or several hundred leaflets. This method would have required too much time to count enough whole plants to get a representative average soon enough after the spraying, with the variation in infestation between plants as great as it was. It also was too inaccurate because of the difficulty of keeping the examined parts separate from the others and because of the rubbing together of the many parts of the plant, knocking off the aphids. A method was used by which 50 leaves were examined in each spray plot. These 50 leaves were removed from 10 plants selected at random at fairly uniform intervals along one of the two middle rows of the plot. Five leaves were taken from each plant at random except for the condition that they were taken respectively from the uppermost, middle upper, middle, middle lower, and lowermost parts of the plant. The results of the counts on plots 7 to 12 are given in Table 3.

TABLE 3.

Aphid distribution on leaves in test plots July 31, 1921.

Plot No.	Treatment on July 30	Position of leaves on plant					Total number of aphids	Percentage of aphids on leaves at soil
		At top	Near top	At middle	Near soil	At soil		
		Number of aphids on ten leaves on ten plants						
7	Bordeaux alone	10	8	15	17	67	117	57
8	Nicotine sulphate[1] 1/800[2]	7	8	13	12	31	71	44
9	Nicotine sulphate[1] 1/400[3]	2	4	7	8	34	55	62
10	Nicotine sulphate[1] 1/200[4]	0	0	1	4	29	34	85
11	Bordeaux alone	6	5	15	18	49	93	53
12	Do	7	3	12	20	43	85	51

[1]In the form of "Black-leaf 40," applied twice on July 30 as described in text.
[2]Or at the rate of ½ pint to 50 gals.
[3]Or at the rate of 1 pint to 50 gals.
[4]Or at the rate of 2 pints to 50 gals.

Apparently the total number of aphids was reduced with increasing amounts of nicotine applied. With the greatest amount applied, in plot 10, they had been practically eliminated from the upper parts of the plants. However, even here many were still left on the lower leaves. This is not surprising in view of the fact that the high-ridge system of culture is followed in this region and consequently many leaves even in addition to those coming from the lowest part of the stems are lying on the ground after the plants begin to sprawl. The drag-bar had been tested on the supposition that the aphids of the species concerned here were usually most abundant on the upper part of the plant, but the counts here showed that they might also be common on the lower leaves. The result was that even the most effective spraying left a reservoir of aphids from which the infestation might be renewed. The cost of one spraying as made in plot 10, requiring at least 6 pints of nicotine sulphate for 150 gallons, the minimum for a double application per acre, would be a matter of considerable concern even if effective. Therefore it seemed best to postpone further attempts to control aphids until the general value of dusting, of nicodusts, and of aphid elimination by insect cages, could have been demonstrated.

DUSTING AND SPRAYING TESTS IN AROOSTOOK COUNTY IN 1922

As stated previously, a revival in the interest shown regarding the dusting of potatoes occurred in Aroostook County in 1922. As one result, the Maine Agricultural Experiment Station undertook to coöperate with several other organizations and individuals in a comparison regarding the effectiveness of dusting and spraying as disease-control measures in Aroostook County, promising to furnish plans permitting an accurate comparison, to examine the test plots regarding disease, and to make the conclusions available to those who might desire them.

Comparisons were made in the fields of two growers whose coöperation was enlisted by the County Agent, and on Aroostook Farm. In planning the four plots wherein tests were made, the four-row sections were arranged so that sprayed sections intervened between dusted and untreated sections, in order to prevent the drifting of dust upon the untreated rows. This also was intended, as was the interposing of at least one sprayed section between other sprayed sections, to make it unnecessary to use rot determinations made in treated rows next to untreated rows where the late-blight spores could easily gain access to the tubers of plants with healthy foliage.

In general the season was very rainy at first[6] so that late-blight infection centers appeared early in this region and the plants grew to be large before it was possible to use machinery in the fields. Then later there was very little rainfall, and the dry weather seemed to check the development of late-blight and to cause the early death of whole fields. Such prematuring is usually, and was in 1922, less pronounced on land not bearing potatoes the year before, and on Caribou loam as compared with Washburn loam and sandy areas.

Kierstead Farm Test

On the farm of Mr. Freeman Kierstead, between the villages of Presque Isle and Caribou, a plot was laid out in an Irish Cobbler field on Caribou loam used for the first time in three years

[6]See Table 16. Over 11 inches of rain fell in June at Presque Isle, as recorded by the observer stationed at Aroostook Farm.

for potatoes. The arrangement and treatment of plot sections was as follows:

Highway on east side.
Rows 1 to 12, sprayed.
Rows 13 to 16, untreated except for chewing insects.
Rows 17 to 20, sprayed.
Rows 21 to 28, dusted.
Remainder of field to west, dusted.
Sprayed Green Mountains on south, and grassland on north.

The record furnished by Mr. Kierstead as to the applications made, shows that in the test on his farm there was freedom from wind at two of the five times of dusting, and presence of dew at four times, including the two with calmness. As estimated 8 pounds of dust was applied to about one-sixth of an acre giving a rate of about 48 pounds an acre[7], but estimation of the amount of dust used is difficult. At the times of spraying it was clear, or both clear and windy, at the two times when the leaves were wet with dew. The usual estimate of 25 gallons gave a rate of about 75 gallons an acre[7]. The machines used were a Niagara power 8-nozzle 4-row recent-model duster and a traction 8-nozzle 4-row sprayer. The materials were a copper-lime dust, once containing poison, and home-made 5-5-50 Bordeaux Mixture prepared with the diluted copper-sulphate and lime solutions poured into the spray tank simultaneously.

Observations on this test-plot made by the writer on July 22 and August 1 showed no injury except on the untreated section, where on both dates there was spray burning due to the use of an insecticide alone which is recommended only in combination with Bordeaux Mixture, and where on the latter date there were many late-blight spots. On August 20, word had been received that the dusted section was going down before the sprayed, and the writer made further observations. In the untreated section about half of the plants were dead and the rest, except about 5 per cent of the total, were dying. This prematuring was apparently due in small part to late-blight and in large part to early blight. In the dusted section about half of the plants were dead or dying, and in the sprayed section about 5 per cent were the same, due apparently to early blight alone. Prematuring was worse toward

[7]See Table 6 for metallic-copper equivalents.

the southern ends of the sections, on higher ground, and was generally worse by August 26 than on August 20.

At digging on September 8, the marketable tubers from four untreated rows (13-16), four dusted rows (21-24), and four sprayed rows (9-12), each group of rows having an area of 1/12.2 acre, amounted respectively to 7.1, 9.1, and 9.9 barrels[8], giving rates of 87, 111, and 121 barrels an acre (239, 305, and 333 bushels). The yield rate was decreased by rot slightly (about 3 barrels an acre) for the dusted and sprayed areas, and it was estimated that there were enough rotten potatoes in the untreated section to account for several barrels, or at least enough to account for the difference below the yield of the dusted section; it seemed impractical and inadvisable to measure the diseased tubers, of which many were wasted away with soft rot. The conclusions from the Kierstead test-plot are that both dusting and spraying eliminated late-blight foliage injury and reduced heavy loss from rot, that spraying postponed prematuring more than dusting, and that aside from controlling rot, spraying increased the yield somewhat while dusting did not. The value of these conclusions is lessened by the limited number of plot sections and by the spray-burning of the foliage of the untreated section.

GETCHELL FARM TEST

On the farm of Mr. Dennis F. Getchell, near the village of Limestone, a plot was laid out in a Green Mountain field on Caribou loam used for the second successive year for potatoes. The arrangement of plot sections was as follows:

Part of field sprayed, but not in test-plot, on west.
Rows 1 to 12, sprayed.
Rows 13 to 16, untreated (except with Paris Green for chewing insects) at south end, and remainder sprayed.
Rows 17 to 20, sprayed.
Rows 21 to 28, dusted.
Part of field dusted, but not in test-plot, on east.
Dusted potatoes to the north, and highway to the south.

[8] A barrelful or "barrel" is considered as equivalent to 165 lbs. See footnotes of Table 5.

The record furnished by Mr. Getchell as to the applications made, shows that in the test on his farm there was freedom from wind at three of the five times of dusting and presence of dew at two times coincident with calmness. At the times of spraying it was clear, or both clear and windy, except once and then the leaves were not dry. The machines used were a Niagara power 4-row duster of an old type with 8 small nozzles, and a traction 8-nozzle 4-row sprayer. The materials were as for the Kierstead farm.

Observations on the test-plot were made by the writer on two dates before the vines were killed by frost. On August 20 the untreated section was somewhat brown because of early blight with the mosaic hills dying, while the dusted and sprayed sections had little early blight and looked healthy, but not quite so good as the sprayed part of the field to the west which had received one more application. On September 9 the plants in the untreated section were all dead and dried up, as were also many plants in the dusted and sprayed sections. The dusted sections were browner and the rows were less full than in the sprayed (see Fig. 30). The crop was the second successive one of potatoes on this field, which accounts for some prematuring.

At digging on October 2, a handful (literally) of rotten tubers were found in the untreated section and none elsewhere. This section (1/11 acre) yielded 6.7 barrels and similar sized parts of the dusted and sprayed sections yielded 8.0 and 7.5 barrels respectively, giving rates of 74, 88, and 83 barrels an acre (204, 242 and 228 bushels) for control, dust, and spray. Rows 2, 4, 6 and 8 (sprayed) yielded 45.0 barrels, or at a rate of 94 barrels (259 bushels) an acre, and rows 22, 24, 26 and 28 yielded 45.6 barrels, or at a rate of 95 barrels (261 bushels) an acre, each group of rows covering 1/2.1 acre. The conclusions from the Getchell test-plot are that there is sometimes, as here, no chance to test late-blight control in Maine because of conditions not allowing the disease to develop, that both dusting and spraying postponed prematuring and increased the yield somewhat, and that even with somewhat greater prematuring, dusting gave a slightly greater yield than spraying.

Aroostook Farm Early-Planted Test

On Aroostook Farm, the Experiment Station experimental farm south of the village of Presque Isle, a plot was laid out[9] in an early-planted Green Mountain field on Caribou loam. The arrangement of plot sections was as follows:

Rows 1 to 4, sprayed.
Rows 5 to 8, sprayed.
Rows 9 to 12, untreated except for chewing insects.
Rows 13 to 16, sprayed.
Rows 17 to 20, dusted with Dosch materials.
Rows 21 to 24, dusted with Dosch materials.
Rows 25 to 28, sprayed.
Rows 29 to 32, dusted with Niagara materials.
Rows 33 to 36, dusted with Niagara materials.
Rows 37 to 40, sprayed.
Rows 41 to 44, untreated except for chewing insects.
Rows 45 to 48, sprayed.
Rows 49 to 52, sprayed.
Rows 53 to 56, sprayed.
Rows 57 to 60, sprayed.
Rows 61 to 64, sprayed.
Sprayed potatoes to east and west, and grassland north and south.

The record made by the senior writer as he directed the applications shows that it was calm or nearly so at four of the six times of dusting, with dew present at five times, and both together at three times. At the times of spraying it was clear or windy or both, with the leaves dry every time. The duster was of the same type as for the Kierstead plot. An old traction 8-nozzle 4-row sprayer, with an unreliable pressure gauge, was used for the first four applications, and after that a new sprayer of a similar type giving 200 lbs. pressure. The spraying materials were as reported for the Kierstead and Getchell farms, applied at the rate of 100 gallons an acre, containing about 2.5 pounds of metallic copper (see Table 6). Here the dusted test-plot sections were not essentially part of a large field, as on the other two farms, with the dust-reservoir full and the outlet gauge set as usual so that a steady known rate of flow was assured, but it was a case of measuring into the reservoir what was needed for half an acre and then regulating the flow as well as possible while watching it

[9] With the help and advice of Dr. W. J. Morse.

and estimating its volume. This regulation of flow was made difficult by the fact that before being used the machine, a borrowed one, had to be emptied with the outlet wide open, so that the gauge which had considerable by-play had to be reset. Another difficulty was variation in consistency of the materials in the reservoir in correlation with the position in the bought 100-pound lot (packed more in the bottom) and in correlation with the amount left in the reservoir or hopper. (Faster flow as less was left). These difficulties only added to the amount of dust applied, and apparently did no harm aside from decreasing the value of estimates of the amount used. Because of wet soil, on this early-planted plot the first application was postponed until a week or more after the plants were large enough to need it. Lead arsenate in water was applied to the "untreated" sections on July 24.

Observations on the test-plot here were made frequently by the senior writer. Small amounts of late-blight injury to the foliage were found by July 23 in an untreated section (Rows 41-44), and more of it by August 12 in spots in both untreated sections, but such injury did not increase much thereafter and was absent from the sprayed and dusted sections. By August 19 the untreated sections were somewhat lighter green than the others and were made further unlike them by the appearance of early blight. The superiority of color in the dusted and sprayed sections over that in the untreated sections is shown in Fig. 31 as well as could be photographed on August 29. By September 5 the untreated sections were conspicuous dark brown streaks across the plot while the dusted sections were somewhat yellow and almost as bad looking as the untreated controls had been on August 29, a week before, while the sprayed sections were uninjured yet. The browning in the untreated sections was due mostly to early blight and flea beetles, with perhaps 5 per cent due to late-blight and with mosaic (present in about 17 per cent of the hills) hastening prematuring. The change from August 29 to September 7 can be seen by comparing Fig. 31 with Fig. 32, in photographs taken from the same places on the respective dates. Low temperatures on September 7, 8, 18, 19, and 21 helped to kill the foliage. By September 14 the difference between dusted and sprayed sections had disappeared because of frost injury to both, and the untreated sections were dead. Digging was done on September 27 and 28.

TABLE 4.

Yields on Aroostook Farm, early-planted plot, 1922.

Section	Yield	Yield rate per acre		Remarks
Rows	Bbls.	Bbls.	Bushels	
1 to 4, sprayed	12.3	94.7	260	Part in a mud sag.
5 to 8, sprayed	12.0	92.4	254	Do.
9 to 12, untreated	10.7	82.4	227	Do. Including 1 per cent rotten.
13 to 16, sprayed	11.0	84.7	233	Part in a mud sag.
17 to 20, dusted	11.3	87.0	239	Do.
21 to 24, dusted	11.7	90.1	248	Do.
25 to 28, sprayed	11.9	91.6	252	
29 to 32, dusted	11.6	89.3	246	
33 to 36, dusted	11.9	91.6	252	
37 to 40, sprayed	12.2	93.9	258	
41 to 44, untreated	10.9	83.9	231	Including 1 per cent rotten.
45 to 48, sprayed	12.3	94.7	260	
49 to 52, sprayed	12.2	93.9	258	
53 to 56, sprayed	12.5	96.3	265	
57 to 60, sprayed	11.7	90.1	248	
61 to 64, sprayed	11.0	84.7	233	

According to the original plans, each plot section consisted of four rows, this being the amount covered at a time by either machine. At digging, each section, having an area of 1/7.7 acre, was dug separately and the yield was measured. The yields, and the yield rates calculated from them, are given in Table 4. A few significant comparisons can be made. Rot was confined to untreated sections, but its scarcity reduces the value of work on this plot as a test of rot-control measures. The question then arises as to the so-called stimulating effect of copper applications and as to the effects of prematuring on yield. First, similarly treated adjacent sections should be compared to determine the field variation due presumably to soil differences.

Rows	Yield rate (bbls.)
1 to 4	94.7
5 to 8	92.4
Difference	2.3
17 to 20	87.0
21 to 24	90.1
Difference	3.1
29 to 32	89.3
33 to 36	91.6
Difference	2.3

45 to 48.....94.7
49 to 52.....93.9
Difference 0.8

49 to 52.....93.9
53 to 56.....96.3
Difference 2.4

53 to 56.....96.3
57 to 60.....90.1
Difference 6.2

57 to 60.....90.1
61 to 64.....84.7
Difference 5.4

The total of the differences is 22.5, giving an average of 3.2, which may be considered as the least difference in yield rate that has real meaning on this field, when making further comparisons. The effect of spraying through the postponement of maturing together with any stimulation that may have occurred, is shown by the following comparisons of yield rates.

Average of all (10) sprayed sections.....91.8
Average of the two untreated sections.....83.0
Difference as effect of spraying.....8.8

Rows 9 to 12, untreated.....82.4
Average of two sprayed sections adjacent to the preceding.....88.6
Difference as effect of spraying.....6.2

Rows 41 to 44, untreated.....83.9
Average of two sprayed sections adjacent to the preceding.....94.3
Difference as effect of spraying.....10.4

A consistent marked increase in yield rate therefore resulted from spraying. A comparison of the effects of spraying and dusting on yield rates is as follows:

Average of all (10) sprayed sections.....91.8
Average of all (4) dusted sections.....89.5
Difference in favor of spraying.....2.3

Average of two dusted sections, rows 17 to 24.....88.6
Average of two sprayed sections adjacent to the preceding.....88.2
Difference in favor of dusting.....0.4
Average of two dusted sections, rows 29 to 36.....90.5
Average of two sprayed sections adjacent to the preceding.....92.8
Difference in favor of spraying.....2.3

Rows 25 to 28, sprayed	91.6
Average of two dusted sections adjacent to the preceding	89.7
Difference in favor of spraying	1.9

While in general the differences in yield rate favor spraying over dusting, these differences do not exceed the previously determined field variation and are not necessarily significant. If the suggestion that sprayed sections next to dusted sections received some benefit from drifted dust is considered here, as it was in planning the arrangement of sections, comparison might be restricted to the following:

Average of the 7 sprayed sections not adjacent to dusted sections (rows 1 to 8, 45 to 64)	92.4
Average of the 4 dusted sections	89.5
Difference in favor of spraying	2.9

Inasmuch as the difference in favor of spraying is greater for sections distant from dusted rows than when including the sprayed sections next to dusted sections, it seems that drifted dust did not add much to the apparent benefits of spraying. It was thought at the time of making most of the applications, that by far the most of the dust remained where the application was made, the drifted cloud appearing to be extremely tenuous.

The conclusions from the Aroostook Farm early-planted plot are that absence of spraying favored only a slight development of late-blight foliage injury and rot, and favored conspicuous prematuring involved with early blight and flea-beetle injury, while spraying eliminated the late-blight and reduced the prematuring; that spraying increased the yield; that dusting was as effective as spraying in eliminating the slight late-blight injury; and that dusting, although accompanied by greater prematuring and somewhat lower yields, was not significantly different from spraying in influencing the yield rate.

Aroostook Farm Late-Planted Test

When the plot was laid out that is discussed in the preceding section of this bulletin, another similar plot was laid out with a corner contiguous to the former but planted later and containing smaller plants—about ready for the first application instead of being already too large. The soil was also somewhat more fertile,

fewer wild daisies *(Chrysanthemum leucanthemum)* and more clover having been grown on the land during the preceding season. The arrangement of plot sections was the same, with the direction of numbering proceeding in the opposite direction, and the plot ended with Row 44. The conditions of the applications given in the preceding section apply also to this plot, except that here the amount of dust applied the third and fourth times was not over 30 pounds an acre, and also by mistake Rows 41 to 44 were sprayed once during the second half of July.

Observations of the foliage disclosed no late-blight injury up to August 12 except in low places in rows 9 to 12, untreated, and such injury was less apparent on August 25 in rows 41 to 44, sprayed only once, than in the untreated section. Prematuring began later than in the early-planted plot, appearing as early blight injury on August 25 in the untreated section, where the browning was not so severe on September 5 as in corresponding sections in the early-planted plot.

TABLE 5.

Yields on Aroostook Farm, late-planted plot, 1922.

Section	Yield	Yield rate per acre		Remarks
Rows	Bbls.	Bbls.	Bushels	
1 to 4, sprayed	12.3	94.7	260	
5 to 8, sprayed	12.0	92.4	254	
9 to 12, untreated	10.4	80.1	220	Including 7 per cent rotten.
13 to 16, sprayed	11.4	87.8	241	
17 to 20, dusted	12.5	96.3	265	
21 to 24, dusted	12.4[1]	95.5	263	
25 to 28, sprayed	13.2	101.6	279	
29 to 32, dusted	12.7	97.8	269	
33 to 36, dusted	12.9	99.3	273	
37 to 40, sprayed	13.0[2]	100.1	275	
41 to 44, untreated[3]	12.8[4]	98.6	271	Including 2 per cent rotten.

[1]Net weight 2070 lbs., averaging 166.9 lbs. per barrel.
[2]Net weight 2160 lbs., averaging 166.2 lbs. per barrel.
[3]Except for one spraying made by mistake during the second half of July.
[4]Net weight of 12.5 barrels of sound tubers 2075 lbs. averaging 166.0 lbs. per barrel.

Digging, done on September 28 and 29, disclosed rot, yields, and yield rates as given in Table 5. Here rot injured 7 per cent of the tubers in the untreated section and 2 per cent in the section sprayed once, while it was eliminated by several dustings or sprayings. Field variation was as follows:

Rows	Yield rate (bbls.)
1 to 4	94.7
5 to 8	92.4
Difference	2.3
17 to 20	96.3
21 to 24	95.5
Difference	0.8
29 to 32	97.8
33 to 36	99.3
Difference	1.5

The total of the differences is 4.6, giving an average of 1.5 as the least difference that is significant. The effect of spraying on yield rates is shown as follows:

Average of the 5 fully sprayed sections	95.3
Untreated section, rows 9 to 12	80.1
Difference as effect of spraying	15.2
Rows 9 to 12, untreated	80.1
Average of two sprayed sections adjacent to the preceding	90.1
Difference in favor of spraying	10.0

A considerable increase in yield rate therefore resulted from spraying. Comparisons of the effects of spraying and dusting on yield rates is as follows:

Average of all (5) fully sprayed sections	95.3
Average of all (4) dusted sections	97.2
Difference in favor of dusting	1.9
Average of two dusted sections, rows 17 to 24	95.9
Average of two sprayed sections adjacent to the preceding	94.7
Difference in favor of dusting	1.2
Average of two dusted sections, rows 29 to 36	98.6
Average of two sprayed sections adjacent to the preceding	100.9
Difference in favor of spraying	2.3
Rows 25 to 28, sprayed	101.6
Average of two dusted sections adjacent to the preceding	96.7
Difference in favor of spraying	4.9

These comparisons hardly favor one method decidedly over the other, though slightly favoring spraying.

The conclusions from the Aroostook Farm late-planted plot are that absence of spraying favored late-blight foliage injury and

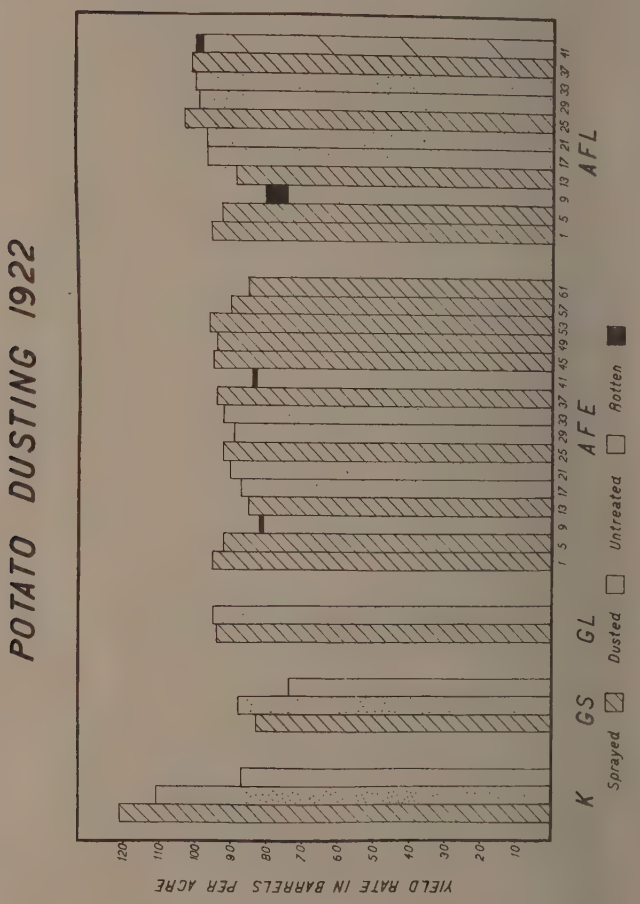

FIG. 24. Diagram showing yield rates of the various four-row sections dug on the four test plots of 1922. Estimated enough rotten in Kierstead field (K), untreated section, to bring total yield up to that of dusted section. The Getchell full-length sections (GL) include the dusted and sprayed short-length sections (GS). The number of the first row of each section is indicated in the Aroostook Farm early-planted (AFE) and late-planted (AFL) plots.

rot and favored prematuring involved with early blight and flea beetle injury, while spraying eliminated the late-blight and reduced the prematuring; that spraying increased the yield; that dusting was as effective as spraying in eliminating late-blight injury; and that dusting, while accompanied by greater prematuring, was either worse or better than spraying in regard to yield rate, depending on what plot sections are compared.

Discussion of Results from the Tests of 1922

The results from the four test plots considered in the preceding pages are summarized graphically in Fig. 24. The percentage of rotten tubers was respectively 0, 1, 7, and about 20, confined to the untreated sections except for the last-named where both sprayed and dusted sections had about 3 per cent. Therefore as far as rot was concerned, dusting did as well as spraying but neither had much chance to show what it could do in the way of prevention. Disregarding late-blight effects, prematuring involved with early blight and flea-beetle injury was most pronounced in untreated sections and as a result the yield rates were reduced below those of sprayed sections. Prematuring was more pronounced in dusted sections than in sprayed sections but the yield rates of dusted sections were essentially as high as those of sprayed sections except in the Irish Cobbler test. Therefore spraying and dusting increased the yield exclusive of the control of late-blight. No explanation is known for the variation among the four plots in late-blight injury. On the two Aroostook Farm plots, while one commercial supply of dust gave greater yields the other compared more favorably with adjacent sprayed sections, and both were apparently alike in foliage symptoms and variation in yield. Whether the use of Irish Cobblers, or the weather conditions holding in these tests, make dusting less effective are questions considered more fully in respect to the next year's experiments.

DUSTING AND SPRAYING TEST ON AROOSTOOK FARM IN 1923

The high cost of dusting materials apparently caused a great reduction in the interest shown in dusting by Aroostook growers but the Station Council advised continuing the tests at least on

Aroostook Farm. A test was made in the field lying immediately to the east of the late-planted test of 1922. The arrangement of the plots was as follows:

Grassland on east side.
Green Mountain plot O-1-b, one row, control and buffer.
Green Mountain plot O-1, 4 rows, control.
Green Mountain plot S-1, 8 rows, sprayed.
Green Mountain plot D-1, 8 rows, dusted.
Green Mountain plot O-2, 8 rows, control.
Green Mountain plot D-2, 8 rows, dusted.
Green Mountain plot S-2, 8 rows, sprayed.
Green Mountain plot O-3, 4 rows, control.
Green Mountain plot S-3, 8 rows, sprayed.
Green Mountain plot D-3, 4 rows, dusted.
Irish Cobbler plot D-4, 4 rows, dusted.
Irish Cobbler plot S-4, 8 rows, sprayed.
Irish Cobbler plot O-4, 4 rows, control.
Irish Cobbler plot S-5, 8 rows, sprayed.
Irish Cobbler plot D-5, 8 rows, dusted.
Irish Cobbler plot O-5, 8 rows, control.
Irish Cobbler plot D-6, 8 rows, dusted.
Irish Cobbler plot S-6, 8 rows, sprayed.
Irish Cobbler plot O-6, 4 rows, control.
Sprayed potatoes on west side.
Grassland on south, and road on north.

A new Niagara power machine was available as the property of the Farm. In order to assure greater uniformity of application of dust, small lots of dust were weighed out and when beginning to dust each 8-row dust plot the amount needed for that plot was put into the hopper. Usually this amount was all applied rather uniformly over the plot, and no dust plot got much more than another. (Plots D-3 and D-4 were treated together as one plot in this respect.) The amount to be applied was at a rate giving 2.5 pounds of metallic copper per acre each application, the same as given by 98 gallons of 5-5-50 Bordeaux mixture per acre. (See Table 6.) A new sprayer was used as in the last part of 1922.

The field record shows that the dust was applied between 4 and 5 o'clock in the morning and the spray several hours later. The spray, 5-5-50 or 5-4-50 Bordeaux mixture using 6.2 pounds of hydrated lime as equivalent to the 5 pounds of stone lime of the formula, was applied at the rate of 80 to 95 gallons an acre, increasing as the season progressed. A 20-20-60 dust was used

twice, a 20-80 dust twice, and a 25-75 dust twice, in the order given, for the six applications of the season.

TABLE 6.

Metallic copper contained in certain amounts of dust and Bordeaux Mixture.[1]

Metallic copper	Dust[2]		Bordeaux Mixture[3]		
	20-80	25-75	4-4-50	5-5-50	6-6-50
Pounds	Pounds	Pounds	Gallons	Gallons	Gallons
1.0	14	11	49	39	33
1.5	21	17	74	59	49
2.0	28	22	98	78	65
2.5	35	28	120	98	82
3.0	42	33	147	118	98

[1]Calculations corrected by Mr. E. R. Tobey of the Dept. of Chemistry.
[2]Amounts calculated on the basis that the number of pounds of metallic copper is equal to the product of three numbers multiplied together—the pounds of dust, the percentage (as a decimal fraction) of monohydrated copper sulphate in the dust, and the percentage of metallic copper in the sulphate.
[3]Amounts calculated on the basis that the number of pounds of metallic copper is equal to the product of three numbers multiplied together—the gallons of Bordeaux Mixture, the number of pounds of crystallized copper sulphate ($CuSO_4$, $5H_2O$) in a gallon, and the percentage of metallic copper in the sulphate.

The field record also shows that the conditions for dusting were good, especially for plot work where drifting is undesirable. That is, it was clear, calm, and dewy. The 25-75 dust could not be applied as uniformly as the 20-20-60 or 20-80 because for the same metallic copper equivalent, less was in the hopper for each plot, and it was harder to regulate the flow as the amount in the hopper was less. Watson's arsenoid[10] was added to the spray at the second application. Lead arsenate was applied to the control plots at the first two applications, except that the buffer plot did not receive a second application. Apparently very few of the eggs of the Colorado potato beetles (potato bugs) and of the flea beetles hatched out, because no second brood was seen. Leaves on the control plots were practically free of flea beetle injury by September 1 (Fig. 33). This was different from the experience of the several years preceding, when both species of insects were at least present and sometimes were abundant. It is thought to be

[10]Containing as an "active ingredient sodium arsenate not less than 80%"

due possibly to an unusually cold rainy spell that occurred after the eggs were deposited (See Table 16, rainfall for July, 1923) inducing fungous injury.

The plants in the Green Mountain control plots were practically free from disease and injury of any kind, as indicated by Fig. 33. About 3 per cent were mosaic. On August 1 slight burning was observed in the sprayed plots, both here and in other fields on the Farm, on the upper rapidly growing leaves along the veins, causing some wrinkling of the leaf surface. During the season the wheels of the spray cart mashed the heavy vines somewhat, doing so more than the duster. On August 2 and August 8 excessive wind bruised the leaves, more so where the mass of vines had been broken down somewhat by the wheels, and some burning, presumably by the copper compounds, developed subsequently where the leaves had been bruised by the wheels and wind. No late blight was seen during the season. A trace of early blight appeared between August 11 and 21 in the control plots. The mass of vines in these plots was noticeably taller on August 31 than in the dusted and sprayed plots. By September 5 every leaf in the control plots had at least one early blight spot on it. On September 12 the control plots still contained the tallest mass of plants. They also had the most early blight, the sprayed plots having very little of it and the dusted plots being intermediate. Killing frosts occurred on September 14 and 20, the first being incomplete in its effects. Digging was done after October 9.

The Irish Cobblers showed about 35 per cent spindle-tuber when dug, and apparently also contained some mosaic that was more or less masked. The vines were not as large as those of the Green Mountains, but the seasonal development of defects was similar. They were dug on September 11 while maturing and "going down."

Only the 4 middle rows were dug in each 8-row plot, in order to avoid the effects of the blowing of dust and spray from any one plot onto the outside rows of adjoining plots. The net weight of the crop from each plot was determined on a large platform scales by difference between the gross weight in the barrels and the weight of the barrels. Knowing the size of each plot and the yield, the yield rate in barrels and bushels per acre was calculated and is given in Table 7, together with the averages.

TABLE 7.

Yield rates per acre in plots on Aroostook Farm, 1923.

Plot No.[1]	Control plots		Sprayed plots		Dusted plots	
	Barrels	Bushels	Barrels	Bushels	Barrels	Bushels
O-1	142	391				
S-1			127	348		
D-1					131	360
O-2	157	431				
D-2					137	378
S-2			127	349		
O-3	150	412				
S-3			132	362		
D-3					139	383
Average for the Green Mountains	150	411	129	353	136	374
D-4					115	316
S-4			109	301		
O-4	115	317				
S-5			110	303		
D-5					117	321
O-5	114	315				
D-6					101	279
S-6			99	271		
O-6	109	299				
Average for the Irish Cobblers	113	310	106	292	111	305

[1]Given in order here as the plots were arranged across the field from east to west, as described on p. 234. Spraying is indicated by S, dusting by D, and controls by O.

The yield rates given in Table 7 show a loss in yield as a result of dusting and a greater loss from spraying. This is true of both varieties, though more so for the Green Mountains. In every case the yield of a sprayed plot is less than the yields of the adjoining dusted or control plots, and in every case but one (plot O-5) the yield of a control plot is greater than the yields of the adjoining sprayed or dusted plots. While the average difference of 21 barrels (58 bushels) between the controls and the sprayed plots does not support the copper-stimulation theory, it is not a surprising result in view of the more perfect foliage mass described for the control plots.

Further comparisons are made in Table 8 by means of calculations which show that there is a significant difference between the different series of Green Mountain plots. In this variety the figures show plainly that the reduction of the yield by spraying greatly overshadowed differences due to variation in soil, fertilizer, seed, etc.

TABLE 8.

Comparison of yield rates of Table 7, giving difference between means and probable error of difference;[1] also ratio between difference and its probable error.

Variety	Mean yield rates compared (in barrels per acre)		Difference between means and P. E. of difference	Ratio between difference and P. E.
Green Mountain plots	Controls, 149.7±2.4	Sprayed, 128.7±1.0	21.0±2.6	8.1:1
	Controls, 149.7±2.4	Dusted, 135.7±1.3	14.0±2.7	5.2:1
	Sprayed, 128.7±1.0	Dusted, 135.7±1.3	7.0±1.6	4.4:1
Irish Cobbler plots	Controls, 112.7±1.0	Sprayed, 106.0±1.9	6.7±2.1	3.1:1
	Controls, 112.7±1.0	Dusted, 111.0±2.8	1.7±3.0	1:1.8
	Sprayed, 106.0±1.9	Dusted, 111.0±2.8	5.0±3.4	1.5:1

[1]Calculated as the square root of the sums of the squares of the probable errors of the means.

DUSTING AND SPRAYING TEST ON AROOSTOOK FARM IN 1924[11]

The results of 1923 when the sprayed plots averaged 21 barrels an acre less than the control plots, made it seem highly desirable to test further the effects of spraying and dusting under different seasonal conditions. The test plots were laid out in 1924 in a field about one-half mile distant from their location in 1922 and 1923, at a somewhat lower elevation and in a location generally less affected by wind. Only Green Mountains were planted and each plot contained 8 rows. The seed was cut so as to approximate and average one ounce to a seed-piece. The arrangement of plots is indicated in Table 9. The area adjoined mostly on land planted with potatoes, and partly on grassland, road, and woodland. The same general equipment and methods were used as in 1923, except that the regular duster engine because of a defective magneto had to be replaced by a lower-power engine until

[11]Field work done by the junior writer, except for some notes on diseases and for the determination of yields.

repairs were made. With a small amount in the hopper in this work, the lower power engine seemed to permit greater uniformity of distribution of material without reducing the thoroughness of its distribution over the plot. Less thorough mixing of the dust will be referred to later. From 140 to 150 gallons of spray was applied at each time. This contained about 50 per cent more copper than the dust. Seven applications were made, the first on July 12 and the last on September 18.

TABLE 9.

Yield rates per acre in plots on Aroostook Farm, 1924.

Plot No.[1]	Control plots		Sprayed plots		Dusted plots	
	Barrels	Bushels	Barrels	Bushels	Barrels	Bushels
O-1	129.6	355.6				
S-1			133.0	365.2		
D-1					126.9	348.9
S-2			136.9	377.3		
O-2	137.2	377.0				
D-2					131.8	362.1
S-3			132.6	366.0		
D-3					126.8	347.9
O-3	131.6	362.3				
Average	132.8	365.0	134.2	369.5	128.5	353.0

[1]Given in order here as the plots were arranged across the field from north to south. Spraying is indicated by S, dusting by D, and controls by O.

The general field record shows that the conditions for dusting were apparently good, as in 1923. Because of the failure of the second brood of Colorado potato beetles and of flea beetles to appear in 1923, there were none to hibernate and to appear in the spring of 1924. Consequently no arsenical was used or needed in 1924. Also, there was an unusual lack of flea beetle injury on the first leaves as compared with the injury of 1918 to 1923 inclusive. On July 23 the plants appeared perfectly healthy as to insects and parasitic diseases. The plants about half covered the ground. (Compare with Fig. 29). About 4 per cent were mosaic.

Some spotting, streaking, and marginal burning appeared in the dusted plots by August 9. This seemed to be copper burning due to imperfection in the mixing of the dust constituents; a high-powered engine might have prevented this through the action of

the stronger currents of air produced. This burning was noted on about 75 per cent of the dusted plants (not affecting much surface on any one plant, however) on August 19, on about 50 per cent on August 28, and on about 85 per cent on September 3. Another kind of burning consisted of a bronzing where chafing occurred due to a leaf's upper surface being rubbed through wind action against the edge of another leaf or against some other irritating object. Both of these kinds of burning were absent from the control plots except that chafing occasionally became evident, but without the burning. The chafing caused more burning in the sprayed plots than in the dusted, up to 40 per cent of the plants showing some by September 3.

Early blight appeared between August 9 and 19. On the latter date some was seen in the sprayed plots. More was seen in the dusted plots and still more in the controls, but the attack was slight even in the controls. A very general infection had developed by September 20 in the controls, but spray continued to control it and dust kept the infection slight. Late blight appeared by September 3. By September 20 it was present on one to several leaflets of every plant in the control plots, but was absent from the sprayed plots and was rarely found in the dusted plots. Both blights had nearly killed the plants in the control plots by September 25. A killing frost occurred on the morning of the 26th.

TABLE 10.

Comparison of yield rates of Table 9, giving difference between means and probable error of difference;[1] also ratio between difference and its probable error.

Mean yield rates compared (in barrels per acre)		Difference between means and P. E. of difference	Ratio between difference and P. E.
Controls, 132.8±1.2	Sprayed, 134.2±0.7	1.4±1.4	1:1
Controls, 132.8±1.2	Dusted, 128.5±0.9	4.3±1.5	2.9:1
Sprayed, 134.2±0.7	Dusted, 128.5±0.9	5.7±1.1	5.2:1

[1]Calculated as the square root of the sums of the squares of the probable errors of the means.

The yield rates given in Table 9 show a loss as a result of dusting and a slight gain as a result of spraying. Technical comparisons made in Table 10 show that the only significant difference is that between the sprayed plots and the dusted plots. The slightness of the gain from spraying would be surprising considering the early death of the controls, were it not for its having happened several times before in this locality. The only plausible explanation for the loss from dusting, which was slight, is the burning described previously as being involved with the use of a low-power engine.

Recent work by Murphy has led to the conclusion that "soil contaminated by means of [late blight] spores shed from the leaves continues capable of inducing blight in freshly dug tubers which are brought into contact with it over a period of at least ten days, and probably longer," (70, p. 368). He thus confirmed previous work by others (70, p. 353-355) as to the danger of early digging and further emphasized soil infection as distinguished from foliage infection. With frost killing the tops so late, and with the untreated tops practically all diseased to some extent, it seemed important to test the effects of delaying digging here. Accordingly, part of the crop dug from the plots at various times was stored in barrels throughout the winter. Very little rot developed in any lot, the kind due to late blight being less injurious than that due to Phoma and to Fusarium, entering bruise cracks. The only lots with an appreciable amount of late blight rot were those dug the day after frost killing, the percentage of tubers by weight, having this rot, being about 1, 6, and 6 respectively for sprayed, dusted, and control lots.

Apparently conditions were unfavorable for late-blight rot infection from the leaves and soil especially when 10 days had elapsed after frost killing. Melhus found that with infected leaves, "a chill sufficient to kill the potato foliage, also kills the spores" (65, p. 19) and, further, that "in cases of rapid drying, six hours was sufficient to kill all spores" (65, p. 16).

DUSTING AND SPRAYING TEST ON AROOSTOOK FARM IN 1925[12]

In 1925 the test was similar to that made in 1924 as to variety, size and number of plots, machinery (including defective magneto), materials, and methods of application. The plots were arranged as indicated in Table 11 and the series was situated on the site of the 1922 late-planted test. About 3 per cent of the hills were mosaic.

From August 1 to 20, inclusive, the meteorological records made at this Farm showed a mean temperature of 66°F. and 3.09 inches of rain. These are conditions which, it will be shown later in this bulletin, seem favorable for the development of late blight in this region. On August 21 a high percentage of plants were infected with this disease in the untreated plots. A trace was noted in the sprayed plots and slightly more in the dusted plots. Early blight was present in the sprayed plots with more in the dusted plots and most in the controls. After this the weather changed, there was a succession of clear days with cold nights, and late blight made no further progress. At digging time, September 30, nearly 1 per cent of the tubers were rotten in one control plot but only a trace was rotten in the other plots. The total yields are given in Table 11.

TABLE 11.

Yield rate per acre in plots on Aroostook Farm, 1925.

Plot No.[1]	Sprayed plots		Control plots		Dusted plots	
	Barrels	Bushels	Barrels	Bushels	Barrels	Bushels
S-1	122	336				
O-1			99	272		
D-1					115	317
S-2	134	368				
O-2			122	336		
D-2					136	374
S-3	139	382				
O-3			128	352		
D-3					135	370
Average	132	362	116	320	129	354

[1]Given in order here as the plots were arranged across the field from east to west. Spraying is indicated by S, dusting by D, and controls by O.

[12]Field work done by the junior author, except for some notes on diseases and for the determination of yields.

Apparently the three east plots were on poorer soil, so that each series showed quite a range. Thus the best control plot outyielded the poorest sprayed and dusted plots, and the middle control plot equalled the poorest sprayed plot and surpassed the poorest dusted plot. On the average the yield was increased 11 per cent by dusting and 13 per cent by spraying. Part of the sprayed and dusted yields were racked in the fall and 5 per cent were removed as culls and as seconds on a screen with 1¾ inch meshes.

The remainder of the sprayed and dusted yields, and the control-plot yields, were left in barrels or bins throughout the winter and racked in May. In barrels, sprayed lots showed a trace of late-blight rot (less than one-half of one per cent), dusted lots showed from a trace to 1 per cent, and controls about 1 per cent. In bins, sprayed stock showed about 1 per cent and control stock about 3 per cent of late-blight rot. In barrels there was no increase of rot with earlier digging, as between stocks dug respectively on September 17, September 30, and October 9. Early-blight rot was absent, the Green Mountain variety being much less susceptible than certain others.

NET PROFITS FROM NINE YEARS' SPRAYING OF GREEN MOUNTAINS ON OR NEAR AROOSTOOK FARM

It was pointed out on p. 217 that in 1921 the then available facts would justify the attempting of effective spraying in Maine against early blight and late blight, and incidentally against flea beetles and leaf hoppers, if the expected cost of spraying would be less than the increase in net returns expected from a fifth larger crop. This estimate was not based on as accurate figures as are available for the spraying of Green Mountains on or near Aroostook Farm 1916 to 1925, omitting 1920. These figures are given in Table 12. For the years previous to 1922 they are taken from reports by Cook (28, 29). Where he had not made determinations of the yield per acre, this was done by the writers using his figures and assuming that the rows in his plots were three feet apart. The chief purpose is to estimate the gain, from spraying, in healthy crop over the healthy crop got without spraying. This is, in brief, to compare the cost of spraying with the net profit it gives. This is not simple because of the many factors of cost

involved, of which each is changed somewhat, relatively, by an increase in the yield from whatever cause.

TABLE 12.

Yields from Bordeaux, dusted, and control Green Mountain plots on or near Aroostook Farm 1916 to 1925 inclusive.[1]

Year	Publication	Yield of control plots per acre		Bordeaux plots. Difference from control plots in yield per acre[2]			Dusted plots. Difference from control plots in yield per acre[2]			Remarks
		Bbls.	Bus.	Bbls.	Bus.	%[3]	Bbls.	Bus.	%[3]	
1916	(28)[4]	129	356	+4	+9	+3	------	------	------	3 plots in each series
1917	(28)	80	221	+23	+62	+28	------	------	------	Excluding rot. 11 plots in each series
1918	(28)	133	379	+5	+13	+3	------	------	------	2 Bordeaux plots and an adjoining control
1919	(29)	111	305	+6	+17	+6	------	------	------	----------
1920	----------	------	------	------	------	------	------	------	------	----------
1921	(29)	150	411	+7	+21	+5	------	------	------	1 Bordeaux plot and a nearby control, on Aroostook Farm
	(29)	116	319	+19	+51	+16	------	------	------	Not on Aroostook Farm
1922	----------	82	227	+10	+25	+11	+8	+19	+9	Excluding rot. 10 Bordeaux plots, 4 dusted, and 2 controls. Early-planted field
		74	205	+21	+57	+28	+23	+63	+31	Excluding rot. 5 Bordeaux plots, 4 dusted, and 1 control. Late-planted field
		78	216	+16	+41	+19	+16	+41	+19	Mean of averages of 2 fields
1923	----------	150	411	−21	−58	−14	−14	−37	−9	3 plots in each series
1924	----------	133	365	+1	+5	+1	−4	−12	−3	Do
1925	----------	116	320	+16	+42	+13	+13	+34	+11	----------
Total	----------	1085	2984	+57	+152	+64	------	------	------	
Ave.[5]	9 years	121	332	+6	+17	+7[6]	------	------	------	
Total[7]	----------	1165	3205	+80	+214	+92	------	------	------	
Ave.[5]	10 years	117	321	+8	+21	+9[6]	------	------	------	
Total	1922-25	477	1312	+12	+30	+19	+11	+26	+18	
Ave.[5]	4 years	119	328	+3	+8	+5[6]	+3	+7	+5[6]	

[1]See the text for details about the securing of these data.
[2]Gain indicated by + and loss by −.
[3]Based on figures in bushels.
[4]Numbers in parentheses refer to Literature cited, at end of this bulletin.
[5]Including only the mean for 1922, and only the Aroostook Farm results for 1921.
[6]Based only on preceding figures in the percentage column.
[7]Assuming 1920 results to be the same as for 1917.

The figures in Table 12 give 121 barrels (332 bushels) an acre as the average yield rate of unsprayed plots in healthy crop at digging. Rot was present only in 1917 and 1922, and in 1917 was as abundant in the sprayed plots as in the unsprayed. Storage rot was determined only in 1924, when it was negligible. The healthy crop per acre was increased 57 barrels (152 bushels) altogether for the 9 years, averaging 6 barrels (17 bushels) a year. This average increase, 17 bushels, is about 5 per cent of the average yield, 332 bushels. This percentage is less than the average of the percentages of increase given in Table 12 for the 9 years, because in 1917 and 1922 the basic yield of the controls was small and the increase as expressed in percentage was therefore larger for each 10 bushels gained than in other years. The conclusion to be advanced is that, in 1926, spraying on Aroostook Farm would seem to be justified as a commercial practice if its cost would be more than covered by an addition of 17 bushels to the crop.

A somewhat simplified financial analysis of the problem is made as follows:

Unit considered, 1 acre of Green Mountains.
Number of spray applications, 6 per season (average of 6 years' records)
Amount applied per acre, 500 gallons 5-5-50 Bordeaux mixture per season.
Total copper sulphate (blue vitriol), 50 lbs. per season.
Cost at 7 cents a lb. $3.50
Total quick lime needed, 50 lbs. per season.
Total hydrated lime used, 62 lbs. per season
Cost at 1 cent a lb. 0.62
Team and two men, 600 gals. applied a day (haul from spray tank to field averaging about ½ mile)
Omit labor on 100 gals. applied anyway for "bugs" leaving labor on 400 gals. per acre applied for copper effect only.
Team and two men, 400 gals., ⅔ day at $9.00 a day 6.00
Original cost of 100-gallon traction sprayer, $250.
Interest on sprayer at 5 per cent, per year, $12.50
Part of interest for 1 acre (1/50 of total interest, assuming it possible for sprayer to care for 50 acres) 0.25
Depreciation per acre per season, assuming sprayer will last 10 years caring for 50 acres (1/500 of cost) 0.50
Annual repair of sprayer for 1 acre, including labor of overhauling (1/50 of $10, total for season) 0.20
Total cost of spraying 1 acre for one season 11.07
Gross receipts from increase of 17 bushels an acre at 70 cents a bushel (80 cents less 10 cents for picking and selling) 11.90

According to these figures a slight gain could reasonably be expected here from spraying in 1926. However, a number of things should be considered before the conclusion is drawn that the small gain here is representative of the region. In the financial analysis of Aroostook Farm spraying, over half the cost is given as being due to labor. This is increased at Aroostook Farm by the long haul due to the location of the spray tank at one corner of the area suitable for potatoes, together with the long, narrow shape of the fields extending away from the spray tank. It is also thought by some students of farming costs that labor used for spraying is largely labor saved, that would not be needed elsewhere at that time of year. The only other high cost is of the copper sulphate. This is probably applied at Aroostook Farm at a higher rate (50 pounds per acre per season) than on many farms where spraying is intended to be thorough. As has been stated (p. 212), Cook concluded that it might be possible to reduce the amount of copper needed by using it in Pickering sprays rather than in Bordeaux mixture. Also, the questions of less copper in Bordeaux mixture and of fewer applications during the season are involved here. These points should be considered in a careful economic study of spraying.

In a study of certain conditions on 58 farms containing 1,633 acres of potatoes in Aroostook County, these farms being better than the average for the County, the cost of spraying materials is given as $4.57, the rate of spraying as 11.9 acres a day, the number of applications of spray as 4.5 times, the man-hours per acre as 4.2, and the horse-hours per acre as 7.7 (36, p. 12 and Tables 8 and 20.) At the man and horse labor rates given (36, Table 11) the labor of spraying cost $3.44, which combined with the cost of materials makes $8.01. These costs can not be compared very intelligently with those at Aroostook Farm. They are based on conditions existing in 1919 instead of 1925. They are involved with the use of only one man to a sprayer. They probably represent the use of fewer gallons per acre, judging from the number of acres covered in a day. With fewer nozzles to a row, with fewer applications per season, and with the probable use of some prepared fungicides, they probably did not have the same effects on diseases, pests, and yields as did the copper spraying on Aroostook Farm. However, they indicate that the cost of spraying at

Aroostook Farm as given in this bulletin is not excessive, especially considering the use of an extra man and of more applications.

The question may also be raised as to whether the smallness of gain in yield given in the financial analysis for Aroostook Farm is truly representative. Do the years in which the figures were obtained constitute a series that is representative of the region concerned in regard to weather, yields, vine growth, insects, and diseases? How representative are the test plots of the region concerned, considering existing differences in variety, vigor of strains, soil and weather conditions, cultural methods, and yields? Are the advantages gained by spraying probably to be increased in the near future by stricter grading of both table and seed stocks and by the help given by disease control toward certification? These questions will be considered in detail, one at a time.

REPRESENTATIVENESS OF THE SERIES OF YEARS INVOLVED

The yield of the control plots was low with the gain from spraying over 10 per cent, in only two of the 9 years involved. A marked loss resulted from spraying in 1923. It would seem as if either the series of years was unduly unfavorable to gains from spraying, or else the region concerned is different from certain other important potato growing regions.

As to the series of years, it is unfortunate that no test was made in 1920, when late blight was severe (see Table 1). Assuming that the results of a 1920 test would have been as favorable to spraying as the 1917 figures, the average for the 10 years including 1920 would have been nearly the same, showing an average gain of 21 bushels instead of 17 bushels. This is still much lower than the gains reported from other regions. As has been pointed out (p. 216), Bordeaux gave an average gain of 60 bushels an acre for a 10-year period in New York and an average gain of 105 bushels for a 20-year period in Vermont (52, p. 247).

The Vermont results for a series of 20 consecutive years show (Table 13) that late blight was bad there in two groups of years, 1892 to 1895 and 1901 to 1905. On this account it may well be concluded that the (corrected) 10 years of tests in Aroostook County are not necessarily representative as to late blight, or even as to weather, normal yields, vine growth, insects, and diseases other than late blight, all of which influence the amount of profit

from spraying. On the other hand, it will be strongly indicated by the facts to be presented, that profit from Bordeaux spraying is not as certain in northeastern Maine as in some other potato-growing regions and is not as great on the average, because of the climate reducing the injuries from insects and diseases and reducing the so-called stimulative benefits of Bordeaux spraying, together with the relatively low farm price per bushel (6, Table 3). Further, an explanation for some of these differences between regions will be offered.

TABLE 13.

Correlation of late blight and August rainfall and mean temperature in Vermont 1891 to 1910 inclusive.[1]

Years of much rot or of much blight and rot			Years of some, little, or no blight and rot		
Year	August rainfall	August mean temperature	Year	August rainfall	August mean temperature
	Inches	°F.		Inches	°F.
1892	8.36	69.4	1891	3.25	70.7
1893	8.31	70.2	1894	1.49	66.0
1895	4.84	69.5	1896	4.09	70.2
1901	3.18	70.8	1897	4.08	67.7
1902	3.17	66.4	1898	4.58	70.5
1903	4.02	64.3	1899	3.82	72.6
1904	2.56	66.7	1900	5.25	70.7
1905	3.98	66.0	1906	2.26	69.0
			1907	1.05	63.6
			1908	1.65	66.1
			1909	2.83	65.3
			1910	2.76	65.2
Average	4.80	67.9		3.10	68.1

[1]Compiled from data published by Lutman (52, p. 292.)

Late blight. In Vermont, Lutman points out (52, p. 293) that "Clearly it is not easy to define the exact weather conditions that call forth an epidemic of *Phytophthora infestans* [late blight]. Doubtless rainfall is the chief factor, but it is one that is limited in its effects by temperature and sunshine and also, probably, by winds." He gives detailed data on the average maximum and minimum temperature and on the rainfall in inches for July, August, and September, and on the prevalence of late blight for each season from 1891 to 1910 inclusive. If the mean monthly temperatures are computed and compared for each month with the rainfall and with the seasonal prevalence of late blight, as done for New Jersey by Martin (61, p. 19), it is seen that there is a

rather striking correlation between late blight and a combination of high rainfall and low temperature in August. This is shown by the data in Table 13, calculated from Lutman's data. The possibility considered was that the disease is usually prepared, as it were, to take advantage of a certain combination of weather conditions and that it becomes serious only when such a combination is presented.

As can be seen from Table 13, 6 years had an August with a temperature of 70°F. or lower combined with a rainfall of 3 inches or more. These are 1892, 1895, 1897, 1902, 1903, and 1905. Of these 6 years, every one but 1897 is listed as a year of much rot or of much blight and rot. The reason for 1897 being an apparent exception is that "tip-burn was prevalent and had already destroyed most of the foliage by the time the late blight appeared, the plants being so nearly dead by the time the Phytophthora [late blight] began its spread that there was a proportionally smaller amount of rot than usual." (52, p. 264). Thus in Vermont the two August conditions mentioned were together *sufficient* for late blight to become severe.

Looking at the same data from a different angle, to see whether the same conditions are *necessary* for severe late blight, 8 years are listed as having much rot or much blight and rot (see left-hand half of Table 13). Of these 8 blight years, 5 have an August with a temperature of 70°F. or less combined with a rainfall of 3 inches or more. The exceptions are 1893, 1901, and 1904. In 1893 the temperature was only slightly above 70°F. and the rainfall was unusually heavy, apparently compensating for the slight highness of the temperature factor. In 1904 the rainfall in August was lower than 3 inches and there was not much blight; then the rainfall in September was the second highest in the record for that month and there was much dry rot. The only puzzling exception is 1901 when even with a high mean temperature, blight and rot were bad; here some unknown factor evidently favored the disease. Except for these 3 years, there are no bad blight or rot years out of a total of 14 years that lack this favorable August combination, the rest having only a small amount of blight and rot, if any. Finally, of the 12 years without much blight or rot (see right-hand half of Table 13) all but one (1897) lack the favorable combination referred to.

In general, therefore, it seems quite plain that in Vermont when the temperature for the month of August is 70°F. or below and the rainfall above 3 inches, conditions are produced that usually result in an epidemic of late blight; and that in the absence of such a favorable combination the disease is not likely to develop. The effect of such a combination may be exerted indirectly in part through humidity, soil moisture, etc.

A similar effect from low temperature and heavy rainfall has been pointed out for New Jersey by Martin, who states that "in New Jersey when the temperature for the month of July is below 74°F. and the rainfall is above 4.74 inches, conditions are produced that are likely to result in an epidemic of late blight." (61, p. 22.) As might be expected in a more southern region with a difference in planting time, in potato varieties, in soil, and in sunlight, the critical month, temperature, and rainfall are not the same as in Vermont, but the fundamental principle is the same. That is, temperature can be too high, or rainfall too low, or both, at a certain stage in the development of the potato plant, to permit late blight to cause serious loss.

Martin also has reviewed the literature on the conditions favoring late blight elsewhere (61, p. 5-7), which can not be done here. It will suffice to say that in practically all the potato growing regions to the south and west of Maine, conditions to become favorable for late blight must become cooler than usual, with other conditions favorable such as moisture, etc. On the other hand, Smith (78, p. 235) suggests that in Maine and other extreme northern parts of the country, and in the higher parts of the Rocky Mountain States, conditions to become favorable for late blight must become warmer than usual, with other conditions favorable.

This theory is tested out in the following correlations made for Maine. There are 29 years in which the monthly mean temperature and total rainfall at Orono are available from the meteorological sections of the annual reports of the Maine Agricultural Experiment Station, together with some record on late blight. Comparing these meteorological factors for June, July, August, and September, following the method of Martin, used in the preceding pages for the Vermont data, with the late blight record in Table 1, no consistent correlation is apparent except for July conditions. This correlation is shown in Table 14. Apparently a

warm and dry July (with mean temperature over 68°F. and with a total rainfall of less than 3 inches) is usually not accompanied by severe blight, while a cool and wet July (with mean temperature less than 67°F. and with a total rainfall of over 3 inches) is accompanied by severe blight. The same fundamental principle is therefore shown here as by the Vermont and New Jersey data.

TABLE 14.

Comparison of July mean temperature and total rainfall at Orono, Me., with general late blight severity in Maine.[1]

Year	Warm and dry July			Cool and wet July			Other conditions in July		
	Mean temperature	Total rainfall	Late blight[2]	Mean temperature	Total rainfall	Late blight[2]	Mean temperature	Total rainfall	Late blight[2]
	°F.	Inches		°F.	Inches		°F.	Inches	
1889							70.6	3.27	++
1890							71.7	3.84	—?
1891							69.7	3.36	++
1896							66	2.58	—[3]
1897							66.6	2.02	++
1898	68.3	2.44	+						
1899							68.4	4.49	+
1900	68.1	2.53	++						
1901	68.6	2.75	+						
1902							64.1	1.81	++
1903				62.1	6.49	++			
1904	68.8	2.43	—?						
1905	68.6	2.19	+						
1906	68.6	2.47	+						
1907				66.9	3.44	++			
1908	71.2	2.85	+						
1909							66.5	2.37	++
1910	69.2	2.43	+						
1911							71.2	4.45	+
1912							67.2	4.60	+
1913							67.9	5.86	+
1914							65.8	2.84	+
1915				65.7	6.67	++[4]			
1916							70.1	4.39	++[4]
1917							70.0	4.05	++
1918							68.5	6.89	+
1919							69.0	4.07	+
1920				66.3	3.36	++			
1921	69.6	1.93	—						

[1]Data from Table 1 and from meteorological sections of annual reports of Maine Agricultural Experiment Station.
[2]Late blight indicated as severe (++), present (+), absent (—), or not noted in record (—?).
[3]Based only on grower's report from northeastern Maine.
[4]Outside of Aroostook County.

With other July conditions at Orono (warm and wet, or cool and dry) the severity of late blight over the State varied. This

TABLE 15.

Transcript from records of temperature at selected stations in Maine for the five months of the growing season.

Station	Month	Normal[1]	Monthly mean (°F.)												
			1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925
Van Buren[2]	August	62.5	.....	60.7	60.0	.....	68.2	66.0	59.5	.....	67.6	60.4	62.6	59.5		
Presque Isle[3]	May	49.9	.....	48.6	53.2	49.6	50.8	43.1	51.0	50.6	51.0	53.4	51.8	46.5	47.4	.....
	June	59.8	.....		59.0	60.6	59.7	59.8	.....		59.3	58.8	62.7	59.2	58.1	60.9
	July	65.8	...	68.7	63.6	64.1	68.1	68.0	.....	.....	64.0	71.8	64.4	62.4	66.6	63.2
	August	63.5[4]	...	61.4	60.2	61.8	71.9	66.9	...	61.6	60.7	60.8	61.2	58.8	61.1	64.9
	September	55.6	.	53.2	55.8	56.5	58.9	53.1	.....	53.7	55.7	56.3	54.7	54.1	52.1	51.5
Houlton[3]	August	65.0	.....	63.6	64.0	65.4	70.0	68.2	63.4	63.4	66.6	67.6	63.8	57.8		
Orono[5]	May	51.28	57.1	50.1	55.8	51.5	54.2	48	57.6	33.8[6]	50.6	53.08	52.55	48.89		
	June	59.37	63.8	61.3	60.8	62.7	61.4	61.5	59.5	60.2	61.6	60.0	61.65	59.65		
	July	65.98	67.2	67.9	65.8	65.7	70.1	70.0	68.5	69.0	66.3	69.50	65.3	62.43		
	August	65.78	62.6	65.2	66.0	66.5	68.9	68.0	65.7	63.1	66.96	62.85	62.5	58.04		
	September	59.44	57.5	56.8	60.0	62.1	59.6	53.0	55.5	55.9	54.1	58.4	56.15	55.89		
Greenville[7]	May	49.5	50.6	47.6	52.1	47.6	49.9	43.2	54.4	51 0	50.0	53.4	52.6	48.6		
	June	58.9	57.0	57.4	56.3	58.8	57.5	58.1	56.6	63.8	59.8	60.0	61.1	60.4		
	July	65.4	65.4	64.4	63.1	63.6	67.4	66.4	66.0	66.6	63.6	70 6	64.6	62.0		
	August	62.5	58.5	62.2	61.9	61.4	65.2	64.7	62.6	60.8	60.6	61.0	63.2	59.2		
	September	55.0	52.9	53.4	56.8	58.4	56.2	53.4	52.2	53.4	56.6	57.2	55.4	56.2		

[1]Normals for Greenville are based on records of 30 or more years of observations, for Orono are based on records of 55 years, for Presque Isle are based on the records for 1914 to 1917 and 1922 to 1923 inclusive, and for Van Buren and Houlton are based on the records for 1913, 1914, 1916, 1917, and 1921 to 1923 inclusive.

[2]Data in letter from G. A. Loveland, Meteorologist, Weather Bureau, Boston, Mass.

[3]Data from duplicates of original records, recalculated for means and totals.

[4]63.0 is the normal corresponding to those for Van Buren and Houlton, i.e., from the same years' records.

[5]Data from section on Meteorological Observations, preceding the index in each annual report of the Maine Agric. Exp. Sta.

[6]Obviously an error, as the absolute minimum is given as 32 and the absolute maximum as 78.

[7]Data from Agricultural Yearbook 1923. U. S. Dept. Agri. Table 786.

is not surprising. In fact, such correlation as is shown in the discussion in the preceding paragraph is more than might be expected in view of the size of Maine and the differences in temperature and rainfall at different meteorological stations. For example, the July rainfall for 1905, 2.19 inches at Orono, varied from 1.45 inches at Houlton, in northeastern Maine, to 5.75 inches at Madison, in west central Maine (57, p. 231).

It will be noted that it is the July records that are most significant in Maine while it is the August records that are most significant in Vermont. There is a difference between the two States in that high temperature frequently is a check in Vermont in July, the mean for 1891-1910 being 70.7°F. (52, p. 292) as against a July normal of 66°F. for Orono (Table 15), while low rainfall frequently is a check in Maine in August, the normal for Orono being 2.34 inches (Table 16) as against an August mean for Vermont of 3.77 inches (52, p. 292). However, this difference would not explain why the July conditions are more significant at Orono than those of August. The only plausible answer seems to be that with a generally low enough temperature in Maine in August (Table 15), the disease if well started in July can often maintain itself during August, in spite of a low average rainfall, because favored by other conditions not considered here. Important conditions that may be suggested as being more or less independent of August precipitation and temperature means are the heaviness of vine growth, the number of rainy, cloudy, or windy days, the relative humidity, and the number and distribution of days hot enough to check the disease.

Making now a similar comparison for the Presque Isle region, where the spraying tests were made that have been described previously in this bulletin, it is found that in the 12 years 1913 to 1924 there are only two records of a mean monthly temperature being over 69°F. (Table 15), so that the temperature would seem low enough for late blight. However, in only 2 of these 12 years (1917 and 1920) was late blight severe. As in Vermont, here also August seems to be the critical month. In the bad blight years 1917 and 1920 the rainfall was over 3.5 inches (Table 16) and the mean temperature between 66°F. and 67°F. for this month. On the other hand, in 9 other years (the 1918 August record not being taken) August either had a rainfall of less than 2 inches with a mean temperature over 71°F. (1916) or had a mean tem-

TABLE 16.

Transcript from records of rainfall at selected stations in Maine for the five months of the growing season.

Station	Month	Normal[1]	Monthly total (inches)												
			1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925
Van Buren[2]	August	3.91	------	2.71	4.16	2.99	1.69	6.02	0.71	------	4.28	5.32	4.23	3.23		
Presque Isle[3]	May	2.48	------	3.53	2.74	3.92	3.45	3.90	4.00	3.32	0.91	1.63	1.55	1.58	3.03	2.32
	June	4.52	------	1.20	4.80	1.95	2.17	7.67	------	1.26	6.08	1.58	11.10	0.82	0.76	3.21
	July	3.06	------	5.18	2.23	3.40	3.68	2.56	------	3.80	4.28	2.49	1.50	4.32	2.09	2.45
	August	3.48[4]	------	3.01	2.05	3.50	1.70	5.32	------	1.75	3.02	5.43	3.88	2.32	3.07	3.09
	September	2.90	------	2.01	2.10	3.25	4.05	1.41	------	4.56	5.21	3.15	1.05	2.98	3.34	4.18
Houlton[2]	August	3.13	------	1.70	1.01	2.17	1.57	4.89	1.51	0.46	------	4.29	5.65	2.80		
Orono[5]	May	3.38	8.05	3.55	1.58	4.97	4.42	3.18	1.69	4.08	1.53	0.71	1.05	1.87		
	June	3.43	2.32	1.38	3.82	2.47	4.99	7.49	2.41	1.44	2.16	1.03	8.06	2.86		
	July	3.44	4.60	5.86	2.84	6.67	4.39	4.05	6.89	4.07	3.36	1.93	2.26	3.86		
	August	2.84	4.69	3.15	3.05	4.67	2.27	4.09	2.58	0.92	2.19	2.44	5.39	1.65		
	September	3.34	3.11	4.42	3.03	1.19	4.60	1.08	4.29	3.07	5.71	2.0	2.10	2.15		
Green-ville[6]	May	3.47	6.32	3.01	1.70	2.99	4.59	3.22	3.37	4.76	1.33	1.97	3.44	2.50		
	June	3.69	1.91	1.82	3.34	2.00	3.99	8.69	3.38	2.25	3.12	2.88	10.00	3.78		
	July	4.24	3.45	5.01	2.62	8.98	5.60	6.97	8.25	5.82	4.46	5.06	3.54	4.34		
	August	3.80	5.38	2.80	2.90	6.13	2.95	4.98	1.42	3.77	4.61	5.56	3.41	2.85		
	September	4.17	4.89	4.30	2.68	3.74	4.23	1.80	6.52	3.71	5.60	3.53	1.89	2.11		

[1]Normals for Greenville are based on records of 20 or more years of observations, for Orono are based on records of 55 years, for Presque Isle are based on the records for 1914 to 1917 and 1920 to 1923 inclusive, and for Van Buren and Houlton are based on the records for 1913, 1914, 1916, 1917, and 1921 to 1923 inclusive.

[2]Data in letter from G. A. Loveland, Meteorologist, Weather Bureau, Boston, Mass.

[3]Data from duplicates of original records, recalculated for means and totals.

[4]3.39 is the normal corresponding to those for Van Buren and Houlton, i.e., from the same years' records.

[5]Data from section on Meteorological Observations, preceding the index in each annual report of the Maine Agri. Exp. Sta.

[6]Data from Agricultural Yearbook 1923. U. S. Dept. Agri. Table 737.

perature of less than 62°F. In the latter case, which has occurred rather often, the low temperature seems to have checked the disease even when rainfall was sufficient, as in 1921 and 1922, although some other condition may have had an important inhibiting effect, such as a hot July in 1921 (mean of 71.8°F.), or an early fall frost (September 7) in 1922, or sunny, drying days correlated with clear, cold nights. Also, seed-piece infection-sources may have been reduced by a dry June in 1921 (1.58 inches of rain) when a number of infected seed tubers produced no plants. (See 66, p. 73, 93, 94 for a similar experience.) Excessive soil moisture (11.10 inches) in June, 1922, apparently helped diseased sprouts to reach the surface of the soil, because infection centers appeared unusually early in the season.

Tables 15 and 16 show the Presque Isle August records to be fairly representative of Aroostook County, with progressively more rain and lower temperature from Houlton in the south northward to Van Buren.

Experience has led local growers in northeastern Maine to expect late blight in warm, moist weather, rather than in cool weather. Thus again northeastern Maine appears to be somewhat different from other potato growing regions in New England as to late blight because of a rise in temperature (or an associated factor) rather than a fall in temperature favoring the disease. This means that it is low temperature rather than high that usually checks late blight here. In Aroostook County chilly conditions in August are often associated with a drying north-west wind. Late blight injury is recorded as being severe outside of Aroostook County but not in it during the 4 years 1889, 1915, 1916, and 1918 (Table 1). That the occasional less severity of late blight in Aroostook County is not necessarily due to better spraying is shown by a report on conditions in 1889, when spraying was not yet practiced and yields up to 738 bushels an acre were obtained there while blight was bad elsewhere and prevented normal yields. (Table 1).

There is also other evidence that it can be too cool for late blight. A record in the files of the Plant Pathology Department of this Station (situated at Orono) states that in 1912 "there was much rainy weather in August but in spite of this little late blight developed." Table 15 shows that the mean temperature for August at Orono was 62.5°F., which is unusually low. Melhus

states that "temperatures between 23° and 27°C. [73° and 81°F.] are more conducive to the growth of the mycelium [of late blight] than lower temperatures, other conditions being favorable." (66, p. 94.) This warmth is seldom maintained long, except in dry, sunny days, with the mean of 62°F. and the range of 25° common for Presque Isle.

Finally, it should be mentioned that "the degree of resistance is not only a varietal character but also depends upon the degree of development of the plant and upon the external conditions during its growth." (31, p. 27.) This has interest with regard to the immaturity of the Green Mountains in most seasons in Aroostook County and the conditions of soil and fertilizer practice which are not duplicated elsewhere.

Early blight. Early blight is a disease first distinguished from late blight in Vermont in 1891 and given this name there in 1892. "despite the fact that it sometimes occurs late in the season" (52. p. 227, 229, and 233.) A yield reduction of about 25 per cent by early blight is usual for certain other important potato growing regions west of Maine (75, p. 3). Our worst year for early blight, accompanied then by some late blight rot and by flea beetle injury, gave only 19 per cent gain from control of all these troubles by spraying (Table 12, 1922). This means about 17 per cent loss from these causes when not spraying. Thus our worst year was not as bad as the average elsewhere.

Rands concluded that "the optimum conditions for an epidemic of early blight require relatively high temperatures alternating with moist periods in combination with a more or less weakened condition of the plant." (75, p. 46). His work suggests to us that the less severity of early blight injury seen in Aroostook County is due to the greater vigor of the plants, the lower temperature, the possibly fewer flea beetles, the moderate rainfall, and the custom of burning the tops as soon as possible after harvesting the crop. The vigor of Maine potatoes is well-known, and is testified to by the yields of 221 to 411 bushels an acre (Table 12) on the poor soil of Aroostook Farm (see p. 263). Their average vigor throughout the growing season is increased usually through their being killed by frost before they begin to mature naturally (see p. 258). The lower temperature has been discussed previously in connection with late blight (p. 255). (See also Tables 13 and 15.) A smaller number of flea beetles even in comparison with central

and southwestern Maine was noted in 1923, 1924, and 1925 by the senior writer, but these observations may be too limited for general conclusions to be drawn. The moderateness of the rainfall during the summer months is shown by Tables 13 and 16. Kincer confirms this (47, Fig. 40), as does also Funk (36, Table 3.)

Tipburn and hopperburn. In Vermont, "Bordeaux mixture, even in years like 1910 when no blight occurs, increases the yield of the plants to which it is applied. This increased yield is always sufficient to pay for the cost of spraying operations." (52, p. 224). It also is of interest that in the same bulletin it is pointed out that "many of the German stations now seem to hold that in northern European climates the bordeaux mixture may so injure the crop as to depress the yield." (52, p. 220.) In Green Mountains in 1910 in the Vermont tests, by September 2, "the unsprayed plants had already suffered considerably more from tipburn than had the sprayed ones." Whether the tipburn was due to hot, sunny, dry weather, to leafhoppers, or to degeneration diseases, all of which are causes of tipburn that have been since shown to be present in Vermont (35; 38, p. 257; 51; 55; 56, p. 28), makes no difference here inasmuch as none of these factors have caused tipburn in the tests with Green Mountains in Aroostook County. While a small amount of sunscald is sometimes seen in Aroostook County, tipburn and hopperburn are at least rare there, if they occur (73), except as tipburn is involved with the burning that is a symptom of certain degeneration diseases under some conditions (35). Therefore tipburn and hopperburn can not be depended upon to pay for spraying in Aroostook County in the absence of other maladies. This seems to be due to the climate inhibiting severe leafhopper infestations rather than to incomplete distribution of the insects (71, p. 153-154.)

Copper stimulation. The question remains as to whether so-called copper stimulation might, in the absence of all pests and diseases, be expected to pay for spraying in Aroostook County. Stimulation has been discussed recently by Lutman (54) and Butler (17) while both reviewing the literature (which need not be done here) and describing illuminating experiments. They have pointed out certain considerations that seem to throw some light on the unusual results obtained in our tests in 1923, wherein Bordeaux mixture caused a loss of 58 bushels an acre with plots triplicated and the difference shown to be significant. (p. 237).

As is seen in Tables 15 and 16, the 1923 Presque Isle mean temperature for July and August was the lowest recorded and the July rainfall was the highest since 1913. The seasonal conditions favored a luxuriant vine growth. (See Fig. 29.) Butler points out the shading effect of Bordeaux mixture on the leaves. The luxuriant growth of the vines in our 1923 test probably caused enough shading, even with the creation of some openings by the spray cart wheels, so that the addition of Bordeaux mixture resulted in excessiveness of shading. It is also pointed out that the work of several authors shows the possibility of Bordeaux mixture retarding the translocation of starch (17, p. 3, 9, and 10; 54, p. 63 and 72), and also the possibility of its lengthening the growing season (17, p. 7, 8, 9, and 17) sometimes without increasing the yield rate (17, p. 17).

It therefore seems reasonably possible that Bordeaux may in some seasons in northeastern Maine cause a decrease in starch translocation that is not compensated by a lengthening of the growing season such as can occur in other regions where the autumnal killing frosts occur later. The days are long in this latitude, which would increase the photosynthetic activity of the leaves and so aggravate the effects of any impediment to starch translocation. The seasons are short, the period of planting usually being May 10 to June 10 and the average date of the first autumnal killing frost, often complete in its effects, being September 12 for the years 1913 to 1924 omitting 1918. (See also 76, Figs. 20 and 29.)

Whether the preceding furnishes a satisfying explanation or not, the fact remains that in the tests in northeastern Maine, both those carried on by Cook and by the writers, there have been several instances of earlier maturity of unsprayed plots without a corresponding increase of yield—in 1916 (p. 210), 1922 (dusted plots), and 1924. Parallels to such instances can be pointed out from other kinds of tests. For instance, in this region we have seen a normally lower-yielding early variety give a greater comparative yield in a short season with an early autumnal killing frost. We have seen, rarely, late-planted healthy Green Mountains approached in yield by early maturing mosaic Green Mountains in early September when the healthy stock was still comparatively immature. Spindle-tuber Green Mountains often appear darker green and so more vigorous than healthy Green Moun-

tains of the same strain, like Bordeaux sprayed potatoes in many tests that have been reported, and further show a corresponding later maturity, but their yield notwithstanding is markedly less. Probably here, too, there is a retardation of starch translocation, as reported for Bordeaux sprayed plants and for potatoes with other degeneration diseases. This retardation is in spite of darker green foliage, or may even contribute to the deeper shade of green, as shown in a certain test with leafroll.

It may be related here how the senior writer in 1924 confirmed a statement made by local growers that Bordeaux applied in sunny weather often causes injury. He noted the effects of an application made on growing Green Mountains on Aroostook Farm on a sunny afternoon. The spray boom happened to be shifted to one side so that the outside part of one row was not covered with the spray. Soon after the application was made, many of the young sprayed shoots were wilted and some even were burned to a crisp. As the sprayer reverted its direction, on each trip across the field, it left unsprayed, unwilted plants, first on the east side of the incompletely covered row and then on the west side, so that it was obviously not a question of unequal exposure to the sun's rays. Also, wilting was not noted previous to the spraying, though the writer was working in the field examining the plants closely. Recovery was observed the next morning except where burning had occurred. This seems to have been possibly another instance of increase of transpiration by Bordeaux spraying (see 17, p. 3, 14, 16-17), but more probably was a toxic effect of the alkalinity of the mixture (19, p. 5.)

Bordeaux injury in other regions. Here it may be pointed out that reports from other regions show occasional lack of benefit from Bordeaux spraying.

In Connecticut, in 1916, in one test vines sprayed with Bordeaux mixture gave a lower yield than the unsprayed vines, using spraying methods that in 15 years' tests had always given a gain. It is explained that in this unusual case "spraying had caused the vines to develop at the expense of the tubers, and this, together with the slight injuries due to the trampling of the vines in the process of spraying, had made the actual tuber development at this time less than that of the checks; then before they had time to catch up, much less to lead the checks, as they undoubtedly would have done due to the protection of the foliage against blight, they

were killed prematurely by the weeds." (26, p. 364.) In the same State in 1917, "the spraying harmed rather than helped in one field, due to trampling of vines in spraying and the premature death of the vines from drought before the effect of spraying showed." (25, p. 420).

In New York in 1909 "as late as September 24 the difference between sprayed and unsprayed rows appeared slight. The sprayed rows held most of their foliage until killed by frost on October 14." Again, in 1911, "until nearly the middle of September the unsprayed rows appeared to be in as good condition as the sprayed ones. On September 15 a contrast was observed for the first time. . . . .The first killing frost came on the night of October 27. . . .Plainly, we have here a striking example of the beneficial influence of bordeaux in the absence of diseases and insect enemies. Of course, the unusually long growing season gave the bordeaux an opportunity to exert its full influence. Had frost come on October 1, as frequently happens, the difference in yield between sprayed and unsprayed rows would have been much smaller; and had frost come on September 14, when potato fields in many localities in the State were killed, the gain from spraying would probably have been very small." (81, p. 108, 111-112.) In fact, in 1913 "this advantage of prolonged growth was lost through the killing of the plants by an early frost" which occurred on the night of September 14. (80, p. 5, 8.)

This shows how the shortness of the growing season in Aroostook County may be expected to reduce the so-called stimulative benefits from Bordeaux mixture. Further, in the former New York report it is stated that in 1904, "in storage, the sprayed potatoes rotted most" (81, p. 103), and that in 1911, "on the rows sprayed seven times the tubers were quite large—so large, in fact, that some difficulty might have been experienced in selling them at full price in the regular potato market." (81, p. 112.) Finally, this report quotes the total expense of spraying as being $4.74 per acre with the net profit $14.43 per acre, the low cost as compared with the Aroostook Farm figures depending mostly on the prewar cheapness of labor.

In New Jersey during ten years' tests, sometimes Bordeaux mixture decreased the yields. Especially interesting is the result secured in "one instance, a spray test conducted in 1922, [where] the average yield of a series of plots sprayed with Bordeaux mix-

ture was 10.8 bushels less than that of adjoining unsprayed check plots. Differences between the sprayed and unsprayed plots were first apparent on October 22 when all of the leaves on the check plots were dead as compared with 25 per cent on the sprayed plots. The night following this observation the green vines were killed by frost thus precluding any possibility of increased returns following the spray application." (63, p. 25-26.) Here again the so-called stimulative effect of copper did not appear as a greater yield produced in a given time, even though it kept more leaves alive, but appeared rather as a promise of a longer life of the plants which would give a greater yield providing frost did not interfere.

In ten years' tests of 5-5-50 Bordeaux mixture at University Farm, St. Paul, Minnesota, from 1908 to 1918 omitting 1915, spraying actually reduced the yield in two years, 1912 and 1913, the reduction being from 17 to 48 bushels an acre using three varieties. A similar reduction is reported for 1895. No explanation is offered for these exceptions to the rule of gains from spraying. (14, p. 15, 16.) There, with an average increase given of about 30 bushels an acre (14, p. 21) and an average cost of about $15 per acre for 5 applications in 1919 (14, p. 28), a field-run price of more than 50 cents per bushel would be required to make spraying profitable.

In Kansas, "five years' results in the potato-spraying experiments show that Bordeaux sprays do not produce an increase in yield in the absence of early blight or tip burn." (45, p. 74.)

In Missouri, tests in 1921 and 1922 showed that increased yield was induced by Bordeaux mixture through longer life of the vines. This was useless in the event of early digging. It was even harmful in one variety, the Early Ohio, because of the formation of second-growth knobs on the tubers, resulting in a lower yield of salable crop. (77).

In Ohio in 1921 and 1922, extensive tests showed general gain from spraying, but in each year a few tests showed no gain in yield (72, p. 249, 250.)

The preceding instances are given only as examples to show that Bordeaux spraying is not an infallible means of increasing the yield, let alone a certain means of increasing net profits. Space is not available to cite more examples, except for reference to some mentioned in a "summary of results and status of the use of

Bordeaux mixture on potatoes" (13: Prince Edward Island, 1916; Rhode Island, 1917 and 1918; Arkansas, 1920; Washington, 1918.)

Conclusions. Admitting that Bordeaux spraying in many potato regions is decidedly profitable on the average, and that the tests in Aroostook County which cast some doubt on the certainty of profits do not cover a long enough period of time to be assuredly representative, nevertheless the evidence indicates that a number of factors exist in this region which tend generally to reduce the profits. Late blight is often checked by high temperature, by low temperature, or by dryness. Early blight is checked by several factors. Flea beetles are often absent. Tipburn and hopperburn are rare. Copper stimulation acting elsewhere through an increase in the length of the growing season is usually prevented from doing so here by an early fall frost. While growing, the large vines are sometimes injured by spraying. Finally, the farm price per bushel is relatively low (6, Table 3) so that a gain of a given number of bushels represents less cash.

These conclusions do not justify a cessation of spraying. The greater uniformity of yield from season to season brought about by spraying, even if got partly through occasional loss in years of heavy vine growth, is of benefit because of the more economical use of storage space over a period of years. There is no correlation between smallness of crop in Aroostook County and the price, which depends on the total production of the nation (36, p. 5-6.)

On Aroostook Farm, where small spraying profits have been disclosed for a certain series of years, rather than to give up spraying it is purposed to develop more economical methods of spraying. It will also be shown, in the next section, that the results on the Aroostook Farm tests are not necessarily representative of Aroostook County.

REPRESENTATIVENESS OF AROOSTOOK FARM TESTS

The variety used was Green Mountain, which is more widely planted than any other variety in Aroostook County. In comparison with Green Mountains, Irish Cobblers appear more susceptible to early blight, and Rose 4 more susceptible to early blight rot. The vigor of the stock used was probably greater in these tests than the average of the stocks of this variety in the County, al-

though by 1924 the planting of Green Mountain seed practically free from degeneration diseases was rather general. The soil was of the better type, Caribou loam, maintained in a three-year rotation instead of bearing potatoes two or more years in succession as is common in commercial fields. Commercial fertilizer has been applied partly on the grain following potatoes instead of entirely on the potatoes, and the amount of clover stubble to be plowed under has been scanty and the potato vines have been less luxuriant than in many commercial fields. Aroostook Farm is mostly exposed freely to a sweep by north-west winds. Whatever the cause may be, in 1925 the destruction by late blight was much greater in many sprayed commercial fields than in the unsprayed test plots on Aroostook Farm. This difference has not been confined to the one year.

From the preceding considerations it seems that in commercial fields with larger, more rapidly growing vines, there would be more profit from Bordeaux spraying than on Aroostook Farm, providing a vine protector were used, through checking a greater amount of late blight injury. Considering a policy of doing no spraying year after year, it would seem reasonable to expect a more rapid development of late blight either in stock planted from seed that is partly diseased, unless unusually careful selection of seed is practiced, or in a field with all parts unsprayed and producing late blight spores unchecked by spraying.[13] That is, in our tests the disease has probably been lighter in our unsprayed plots, which were planted with seed from a sprayed plot and which covered only a third of the experimental field, in scattered areas, than it would have been in the same unsprayed plots with the seed taken from unsprayed stock and with the other two-thirds of the field also unsprayed.

A careful survey extending over at least several years is needed if it is to be shown definitely whether all potato growers in Aroostook County should spray (they do not all do so now) or if it is to be shown what conditions make spraying most profitable.

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[13]Melhus (66) has shown how infected seed is often planted and how one piece of such seed will, under favorable conditions, become a source of blight that will spread over an entire field. The more such seed is planted, the more chances for sources of an epidemic. Overwintering through saprophytic growth in the soil may also be important (31).

A number of conditions may possibly vary from farm to farm with an effect on the profits from spraying with Bordeaux mixture. Butler has shown that the quality of Bordeaux mixture varies with the different practical methods of mixing, of which he describes nine (16, p. 155-156, 162, 177-178; 20, p. 5). For an example of difference in methods, a mixing platform may be used, pouring the diluted copper sulphate and lime together, or else strong lime may be added to diluted copper sulphate in the spray tank (37).

The amount of copper applied during the season varies according to the number of nozzles, the size of nozzle openings, the pressure, and the number of applications. The relative amount of lime and copper used in practice sometimes varies with a desire for an excess of lime to show the presence of the spray materials, or varies with the type of lime used. Butler has shown that under certain conditions the amount of copper applied is of prime importance and that half as much lime as copper is better than equal amounts (21).

The rapidity of growth and the size of plants vary and exert an influence, through making a given amount of spray material a more (or less) complete coating and through making conditions more (or less) favorable for diseases and insects to thrive and injure the plants. Environmental conditions such as soil moisture, slope, exposure to wind, showers, earliness of freezing, and storage conditions, all influence the effects of diseases for which spraying is done. The degree of injury is determined somewhat, at times, by the selection of seed (see p. 263) and by the date of digging (see p. 241).

Until such a survey has been made as has been mentioned, any grower who is in doubt as to the value of spraying on his own farm can test the matter in several ways. A grower who believes and practices non-spraying, but who is in some doubt, can at least spray an eight-row strip through a field and make comparisons, finally digging the middle four rows of the sprayed strip to test the yield both with and without rot against two 4-row unsprayed strips on both sides of the sprayed strip. Sprayed and unsprayed stock should be kept in storage for a month or more for a comparison of shrinkage, as sometimes soil can infect potatoes at digging even after the tops are dead. A record of the spraying and of other conditions observed including costs should be kept and the

test repeated for from five to ten years. If the truth is sought and not a mere confirmation of an opinion, one or two years' results are not reliable. Further, the seed for each year's sprayed stock should be taken from the stock sprayed the preceding year, while the seed for each year's unsprayed stock should be taken from the stock unsprayed the preceding year.

A grower who on the other hand is spraying but who is doubting its value as he has been doing it should first determine whether his methods are similar to those used effectively by others, in case he is not controlling diseases and pests. If his methods seem similar, he can try more drastic measures such as more nozzles to a row, a higher copper content, or more frequent spraying. If, on the other hand, a grower suspects that he is losing money on copper spraying because of insufficient diseases and pests to make it worth while on the average, rather than because of their being too strong for his spraying to control them, he can test the matter by leaving eight rows unsprayed. It should be remembered that eight unsprayed rows in a sprayed field will often do better than the plants in a field that is entirely unsprayed, but nevertheless any comparison should be made in one field because of the importance of having as much soil uniformity as possible.

Probable Future Grading Improvements in Relation to Spraying

Getting a field certified usually increases its value, and control of late blight is specifically required for certification. Late blight rot and the recently distinguished early blight rot (34) cause trouble, especially with the current general development of stricter grading for both table and seed purposes. There is also some evidence of improvement of the vigor-value of seed by spraying (14, p. 19-20; 64). These advantages of spraying probably will be more apparent in the future than they are now.

The Use of a Vine Protector on the Spraying Machine

In 1924 a vine protector was tested that had been supplied for the purpose by the Maine Potato Vine Protector Company of Dexter, Maine. This protector pushed the vines aside ahead of the wheels. The test was made on Green Mountains that had

been sprayed only once previous to August 10. On this date the protector was used on alternate four-row plots during the application of standard materials to a small field 24 rows wide and about 250 feet long. A second application was made similarly on the same day and a third on August 16.

At the first application the protector pushed the vines aside, bending them forward somewhat. It later appeared to have been a mistake to make the second application before the vines had had a chance to grow somewhat upright again as they usually do after being bent over. Another mistake consisted of driving at each application in a direction opposite to that taken the time before; the vines were permanently bent forward enough so that they would have been pushed aside better if the machine had been driven in the same direction for each four rows each time. With these mistakes made, the vines were mashed about as much with the protector as without it.

TABLE 17.

Yield rate per acre in vine protector test, 1924 and 1925.

Plot No.[1]	1924				1925			
	With protector		Without protector		With protector		Without protector	
	Barrels	Bushels	Barrels	Bushels	Barrels	Bushels	Barrels	Bushels
P-1	127	348			143	392		
O-1			128	352			136	374
P-2	131	359			132	363		
O-2			129	355			133	365
P-3	126	347			142	391		
O-3			132	363			137	376
Average	128	351	130	357	139	382	135	372

[1]Given in order here as the plots were arranged across the field from north to south (1924) or east to west (1925). Use of the vine protector is indicated by P and controls by O.

That is, these methods were mistakes on the assumption that prevention of vine injury was of chief importance. However, they were in accordance with the policy of postponing spraying until late blight has begun to appear and then using a vine protector to reduce injury to the plants. When late blight appears at this time, plants may usually be expected to be large, filling the furrows between the ridges, especially if unsprayed. The practice is frequently advocated and followed of beginning to spray

after late blight has appeared, and of then driving in opposite directions in order to cover the foliage better.

After the vines had been killed by frost the yield of each four-row plot was determined as it had been for the spray-dust test and is given in Table 17. It is seen that in yield rate there was considerable overlapping of the two series, with the average in favor of the plots sprayed without the use of the protector. A comparison of the means, as given in Table 18, indicates that this difference may be due to variation in soil or fertilizer application as much as to the disuse of the protector.

The test was repeated in 1925[14] in 24 rows alongside the west plot of the spray-dust test. The spray applications were made as were those of the spray-dust test. The yield rates are given in Table 17. The two highest yields and the lowest yield came from the plots where the protector had been used. Although the average yield rate was in favor of the protector, the range in each series again made this difference nonsignificant scientifically (Table 18). The so-called "without-protector" plots merely had the protector raised by means of the device present for use at turns where the ground is rough. Too late to make a correction, it was noticed that even with the protector raised in this way, it apparently was functioning to some extent brushing aside the vines. Therefore it is possible that there would have been a greater difference in favor of the protector had it been completely removed from the spray cart for the applications on these control plots.

Assuming that the difference of 3.7 barrels (about 10 bushels) in favor of the protector is normal for conditions such as prevailed in the test of 1925, this gain must more than cover the interest on the money invested in the protector, the extra labor costs due to installing and manipulating it, any extra team cost due to the increase in load, and depreciation and repairs. This apparently would be done with a wide margin at 70 cents a bushel for a farm price. The chief need is for greater certainty that the increase is due to the use of the protector rather than to uncontrolled field factors. The 1924 test suggests that the vines will be mutilated least if trained from the time when they begin to fill the furrow, by always driving the machine in the same direction with the

[14]Field work done by the junior writer.

wheels in the same furrows. This applies whether or not a protective device is used.

TABLE 18.

Comparison of yield rates[1] in vine protector test, giving difference between means and probable error of difference;[2] also ratio between difference and its probable error.

Mean yield rates compared (in barrels per acre)		Difference between means and P. E. of difference	Ratio between difference and P. E.
With protector, 1924; 127.7±1.4	Without protector, 1924; 129.7±0.6	2.0±1.5	1.3:1
With protector, 1925; 138.9±1.9	Without protector, 1925; 135.2±0.7	3.7±2.0	1.8:1

[1]Carried out to one decimal place, further than for Table 17.
[2]Calculated as the square root of the sums of the squares of the probable errors of the means.

COMPARISON OF DUSTING AND SPRAYING

As stated previously (p. 217) a revival of interest in the dusting of potatoes led the Maine Agricultural Experiment Station to perform experiments with dust comparing it with standard Bordeaux spraying. General advantages in comparison with spraying that have been pointed out for dusting by its most enthusiastic advocates, H. H. Whetzel, George E. Sanders, and the Niagara Sprayer Co., are: (1) Greater increase of yields through control of diseases and insects and through copper stimulation. (2) Less labor cost. (3) Less interest and depreciation cost on machinery. (4) Greater possibility of more timely applications. (5) Less disagreeable nature of the operation of application.

These advocates of dusting have not been agreed with entirely by other workers. In the following section the results of the other workers mentioned will be briefly summarized. Following that, cost data and the general conclusions from the tests in Aroostook County will be presented.

REPORTS FROM OTHER REGIONS

In a report considering the results and status of the use of Bordeaux mixture on potatoes, it is pointed out that "copper dust

appears valuable, as indicated by the Canada and New York reports." (13, p. 193). In a supplementary report (15) further work with dust is summarized. In Manitoba in 1921, copper-lime dust applied with a hand machine increased the yield much less than 5-5-50 Bordeaux spray.

Results from other sources follow, none referring to the older kinds of copper dust made before the copper-lime type that was developed by Sanders.

In Florida in 1923, copper-lime dust applied with a traction power machine gave a somewhat greater increase in yield than homemade Bordeaux mixture applied with a tank pressure of 175 pounds, at about three times as great a cost. In another field, copper-lime dust applied in the daytime increased the yield 25 per cent while when applied by night it increased the yield 43 per cent (87, p. 107-112). A later report concludes that

"Much experimental work is needed to determine what methods are necessary to secure better commercial control of late blight. The question of relative efficiency of dusting and spraying has not been settled. For dusting, the time of application, the interval of time between applications, the amount of dust to use, the strength of dust to apply, and the relationship between climatic conditions and dusting are all points which need investigating."

In 1924 "early blight. . . . .was severe and was not controlled by any of the dusts, it being as severe in the dusted as in the undusted rows." (40, p. 15-16.) No spraying was done in this test. In 1925

"The dust was applied early in the morning when there was no wind and plenty of moisture on the foliage, and the spray later in the day when the foliage was dry. Approximately 70 gallons of a 4-4-50 Bordeaux mixture per acre per application was applied at 200 pounds pressure and about 21 pounds of copper-lime dust with a guaranteed analysis of 6.8 per cent metallic copper content was applied at each application. In this way about 1.4 pounds of metallic copper was applied in each fungicide. Contrary to last year, late blight but no early blight was present. Commercial control of the former was obtained in all cases. Spots of the disease were seen in both dusted and sprayed rows. The general appearance at one time was that of a field which was just becoming badly infected with the disease.....All check rows were killed by the disease about 15 to 20 days before the maturing of the treated vines.....Approximately the same yields were obtained where the vines were dusted as where they were sprayed. A consistent decrease in yield is observed in the check rows thruout the experiments." (40, p. 17-18.)

In Kansas "considering the results obtained in spraying with Bordeaux mixture for the period 1918-1923 it would seem that the returns have been too small to warrant the cost." (83, p. 3, 39.) As calculated the cost (83, p. 38) was slightly more than that calculated for Aroostook Farm spraying. Copper-lime dust was no better in Kansas than Bordeaux mixture and cost somewhat more. (83, p. 30-39.)

In 1921 in the upper peninsular region of Michigan, hopperburn was severe. In a test wherein copper-lime dust was applied with a hand duster, "the foliage of the dusted rows was deep green in color while that of the check rows had a decided brownish cast due to hopperburn. The dusted rows also compared very favorably with those which were sprayed with bordeaux mixture." (48, p. 24.) In 1922 in the same region, on Green Mountains in replicated plots with hopperburn severe in the control plots, 4-4-50 Bordeaux mixture gave better control and higher yields than copper-lime dust. The latter caused a loss when applied only 3 times with nicotine added. In 1923 and 1924 there were no diseases and pests and no treatment gave an important gain, the supposed stimulative effect of copper spraying not being demonstrated. The cost of dusting was much greater. (49.)

In Minnesota in 1922 and 1923, using power machines and two varieties in replicated plots, four applications of 4-4-50 Bordeaux mixture increased the yield about three times as much as did dust. Leafhoppers only are mentioned as injuring the untreated plants. (50.)

In New Jersey in 1921 and 1922, copper-lime dust did not increase the yield as much as Bordeaux mixture, the difference being due to lack of control of early blight, tip-burn, and late blight by dust. (63, p. 28). A later report including also the results of tests made in 1923 and 1924 concluded that "in every case, regardless of the fungous or insect pest present, the use of Bordeaux mixture gave greater yield increases than did the use of the copper-lime dusts. The average per cent increase for all varieties for the four year period was 1.4 for the dusted and 13.9 for the sprayed plots." (62, p. 74.)

In New York in tests made in 1920, 1921, 1922, and 1923, dust did not control hopperburn, late blight, and late blight rot as well as spray did. These tests were involved to some extent with the use of hand dusters, of spray hose eliminating the driving

through the field, of home-mixed dust, and of excessive amounts of dust (over 130 pounds per acre per application). There was also an occasional greater amount of rot with spraying and an occasional greater yield from check plots than from sprayed. The conclusions though favoring spraying also admitted the desirability of dusting under certain conditions. (82.)

In Ohio in 1921, "the control of hopperburn secured from dust applications, when applied by means of either hand blower or power duster, was greatly inferior to that secured by the spray . . . . .Ten and twenty pounds per acre per application were applied." The spray was 5-7½-50 Bordeaux applied at the rate of 75 to 100 gallons an acre at each application. (72, p. 256, 252.) Here the amount of metallic copper applied per acre was greater for the spray. In 1924 with hopperburn present, Bordeaux mixture applied with a power sprayer increased the yield more than dust (sulphur-lead arsenate for the first application and copper-lime for the other three) applied with a hand machine (84).

In Rhode Island in 1922, "the weather was very conducive to late blight and rot, and the Bordeaux spray caused a two-thirds increase in the yield of sound potatoes of the Rural group. Where Bordeaux dust was applied with a hand duster in comparison with the usual spraying with a horse sprayer, the crop of sound potatoes was only about 70 per cent as great with the dusting as with the spraying." (41, p. 4.) According to these figures, the check yield was 60 per cent of the sprayed, so that dusting increased the yield about 17 per cent as against 67 per cent for spraying.

In Wisconsin liquid sprays for leafhopper injury were valuable, and were more effective at less cost than dusting. (88, p. 64.)

In New Brunswick in 1922 in the Dreer Standard variety, six applications of Bordeaux (4-4-50, 5-5-50, and 6-6-50 being used successively as the season progressed) increased the yield of the controls (228 bushels marketable) by 14 per cent. Dust that was home-mixed, with 12 per cent of dehydrated copper in it, increased the yield by 10 per cent. The same percentage increases were got in total yield as well. (11.) In the same province in 1924, both spraying and dusting increased the yield about 10 per cent (12, p. 44) when applied in amounts with the metallic copper about the same according to calculations from the data presented. With the amount of metallic copper somewhat less for the dust, thus de-

creasing the cost of the material, it still cost slightly more for dusting than for spraying (12, p. 44).

COST DATA

In the preceding section of this bulletin some reference has been made incidentally to the cost of dusting compared with that of spraying. It cost more in Florida, Kansas, Wisconsin, and New Brunswick. In Michigan the assumption was made that dusting was only twice as fast as spraying. However, "the labor figures are not especially significant in this regard since the cost of materials is so large an item," and the total cost is given as more than double that of spraying (49, p. 7). The spraying costs are about the same as have been given for our tests (p. 245).

In our tests in Aroostook County data were got which have been used in making an estimate comparable with the estimate for spraying (p. 245). This estimate would be more reliable if based on more experience, but may serve at least as a guide for future accounting. It is as follows:

Unit considered, 1 acre of Green Mountains.	
Number of applications, 6 per season.	
Total applied per season per acre, equivalent in metallic copper to 500 gallons of 5-5-50 Bordeaux mixture, 175 lbs. of 20-80 material.	
Cost at 8 cents a lb.[15]	$14.00
Team and man, 25 acres covered in a day (with ½ mile haul of materials to the field)	
Omit labor on one application applied anyway for "bugs" leaving labor on 5 applications for copper effect.	
Team and man, 5/25 day at $6.00 a day	1.20
Original cost of gasoline-power duster, $480[15]	
Interest on duster at 5 per cent, per year, $24.00	
Part of interest for 1 acre (1/200 of total interest assuming it possible for duster to care for 200 acres)	0.12
Depreciation per acre per season, assuming duster will last 10 years caring for 200 acres (1/2000 of cost)	0.24
Annual repair of duster for 200 acres, $?	
Repair for one acre	0.25
Gasoline, oil, and grease for 6 applications on 1 acre	
Total cost of dusting 1 acre for one season	15.81

[15]Excluding freight charges.

The outstanding item is the cost of the material. With the same number of applications the amount of dust applied would have to be cut down a third to make dusting cost about the same as spraying. This would mean a cutting down of one-third on the amount of metallic copper. To do this requires the assumption that much copper applied in spraying is not needed, or that copper applied in the form of dust is half again as effective as copper applied in the form of spray. Such evidence as we have does not support this assumption.

Adherence to the Foliage

It is generally conceded, though not universally (85), that the copper is the effective material in Bordeaux mixture or copper-lime dust. Accordingly it was thought desirable to compare these two fungicides as to the adherence of the copper. Various methods of sampling and of analysis have been described in various publications, which need not be reviewed here. Calculations can be made of the copper per acre of soil, per unit of area of leaf surface, and per unit of weight of the green leaves or of the dried leaves. The distribution in space and in time can be studied. Only the methods used here will be described.

The samples were taken in 1923, a season in which about equivalent amounts of metallic copper were applied in the spray and dust. The samples were restricted to Green Mountains in the 4-row strips that later were dug for yield. With modification as the plants became larger, the general manner of sampling was to remove certain leaflets from a hill in each row, repeating this at several intervals along the 4-row strip. From each hill, at the first sampling a leaflet next to the terminal leaflet was removed from each leaf except from the youngest ones. At the second sampling the opposite leaflet was removed from each leaf. Only two samplings were taken from a given set of plants. As the plants became older fewer plants could be sampled at each time. By this method different rows and sections of the plots were represented, all parts of a hill were represented, and a sampling made just after an application could be compared rather closely with one made later, following weathering but before another application. Of course, growth of the leaflets would of itself reduce the copper index which was used, but this growth probably was similar for the dif-

ferent plots. By this method of sampling it was expected to be learned what part of the copper that was passed through the machine actually reached the plants, and what part of the copper that reached the plants weathered off in a few days, as a matter of comparison between spray and dust.

The leaflets as picked with the fingers were dropped into a Manila-paper bag, were dried in the open bag in an electric oven at about 45°C., and were shipped to the main laboratory at Orono for analysis.[16] A quantitative electrolytic method was used, following in general that described by Butler and Smith (22, p. 437-438.) The process was, in brief, as follows: Remove leaves to a porcelain evaporating dish, in which determine the dry weight at 104°C. and burn the leaves to ash. Remove the ash to a Kjeldahl flask, rinsing the dish with dilute sulphuric acid and water, and digest over a gas flame in 30 cc. of C.P. sulphuric acid with about 3 grams of potassium sulphate added, until the liquid is clear. Remove the liquid to a beaker, rinsing the flask with dilute sulphuric acid. Add ammonia in excess, boil a few minutes, and filter. Reduce the filtrate to 50 cc. or to dryness on a steam cup. Make up to 50-100 cc. with distilled water and warm. Add ammonia in excess. Filter into a large platinum dish (weighing about 90 gms.), washing the residue on the filter paper with distilled water until the blue color is gone. This dissolves most of the residue and necessitates a preliminary electrolysis in the ammoniacal solution. Siphon off liquid. If the deposit is of true copper color, wash dish with alcohol, dry, and determine weight of metallic copper. If, as is usual, the deposit is black, dissolve it in nitric acid, dilute, boil for a few minutes, make alkaline with ammonia, boil for a few minutes, and filter. Make the filtrate slightly acid with nitric acid and carry out electrolysis. Siphon off liquid etc. as above determining weight of copper.

The procedure was complicated sometimes by the necessity of making a second preliminary electrolysis of the first siphoned liquid, or by the necessity of testing a black suspension or precipitate in this liquid for copper. The process is laborious and is not of the greatest accuracy, but served to compare sprayed and dusted copper under the prevailing conditions which did not permit analysis to be made where the samples were collected, and is ac-

[16]The senior writer made the analyses. He is indebted to Mr. Elmer R. Tobey, then Associate Chemist, for advice.

TABLE 19.

Adherence of sprayed and dusted copper in test plots of 1923.

Date	Rain in in.[1]	Application	Dry weight in grams of sample from plot[2]:						Metallic copper in milligrams per 10 grams of dry weight from plot[2,3]:					
			O-1	O-2	D-1	D-2	S-1	S-2	O-1	O-2	D-1	D-2	S-1	S-2
7/11	------	-------	------	24.0	------	------	------	------	------	0	------	----	----	----
7/12	------	I[4]												
7/13[5]	------	-------	37.0	10.5	39.6	34.9	42.7	------	T[6]	T[6]	11	17	10	----
7/15	1.80	-------												
7/16[7]	0.60	-------	31.1	33.7	31.9	36.3	34.2	------	T[6]	1	3	1	5	----
7/18[8]	------	II[4]	24.6	24.9	31.3	27.1	27.8	25.1	T[6]	3	16	17	23	28
7/20	0.02	-------	------	------	------	------	------	------	------	------	------	------	------	------
7/24[9]	------	-------	------	------	38.9	28.8	39.8	29.5	------	------	10	10	20	16
7/25	0.28	-------	------	------	------	------	------	------	------	------	------	------	------	------
7/26	0.40	-------												
7/27[10]	0.27	III[11]	20.6	------	25.8	------	23.0	------	1	------	13	----	34	----
7/28	0.23	-------	------	------	------	------	------	------	------	------	------	------	------	------
7/29	0.28	-------	------	------	------	------	------	------	------	------	------	------	------	------
7/30	0.06	-------	------	------	------	------	------	------	------	------	------	------	------	------
8/1[12]	------	-------	21.2	------	27.6	------	22.1	------	0[13]	------	7	----	27	----
8/4	0.06	-------	------	------	------	------	------	------	------	------	------	------	------	------
8/8	0.06	-------												
8/9[14]	------	IV[15]	23.2	23.2	29.0	24.4	28.3	20.9	3	0[13]	lost	14	33	39
8/11	0.17	-------	------	------	------	------	------	------	------	------	------	------	------	------
8/12	0.04	-------	------	------	------	------	------	------	------	------	------	------	------	------
8/13	0.34	-------	------	------	------	------	------	------	------	------	------	------	------	------
8/14	0.15	-------	------	------	------	------	------	------	------	------	------	------	------	------
8/15	0.35	-------	------	------	------	------	------	------	------	------	------	------	------	------
8/17[12]	------	-------	20.9	21.7	30.5	24.4	22.5	20.8	T[6]	0[13]	6	7	24	25
8/19	0.06	-------	------	------	------	------	------	------	------	------	------	------	------	------
8/20	0.06	-------	------	------	------	------	------	------	------	------	------	------	------	------
8/21[16]	0.50	V[17]	34.0	------	35.6	------	28.6	------	3	------	17	----	37	----
8/22	0.32	-------	------	------	------	------	------	------	------	------	------	------	------	------
8/28	0.09	-------	------	------	------	------	------	------	------	------	------	------	------	------
8/29	0.12	-------	------	------	------	------	------	------	------	------	------	------	------	------
9/4	0.12	-------	------	------	------	------	------	------	------	------	------	------	------	------
9/6[18]	------	VI[17]	19.9	------	25.0	------	17.9	------	4	------	19	----	40	----

[1]Complete record as taken for this period at Aroostook Farm.

[2]Plots indicated as in Table 7. Spraying is indicated by S, dusting by D, and controls by O.

[3]Multiply this index by 100 to get parts per million.

[4]Dusted with 20-20-60 at 35 lbs. an acre; sprayed with 5-4-50 Bordeaux mixture at 80 gals. an acre.

[5]Each sample from 48 hills except from plot O-2, 15 hills, reduced because of occurrence of slight shower.

[6]T (trace) signifies less than ½.

[7]Samples taken after rain. Each sample from 48 hills which were the same as for the preceding sampling except for plot O-2.

[8]Samples taken after the application. Each sample from 24 hills except from plot D-1, 32 hills.

[9]Samples from same hills as for preceding sampling except for plot D-2, 20 hills only.

[10]Samples taken after the application and before the rain. Each sample from 12 hills.

[11]Dusted with 20-80 at 30 to 35 lbs. an acre; sprayed with 5-4-50 Bordeaux mixture at 90 gals. an acre.

[12]Samples from same hills as for preceding sampling.

[13]Electrolysis not carried out because of smallness of amount as indicated by color in ammoniacal solution.

[14]Samples taken after the application. Each sample from 8 hills.

[15]Dusted with 20-80 at 30 to 35 lbs. an acre; sprayed with 5-4-50 Bordeaux mixture at 95 gals. an acre.

[16]Samples taken after the application and before the rain. Each sample from 6 hills.

[17]Dusted with 25-75 at 25 to 30 lbs. an acre; sprayed with 5-5-50 Bordeaux mixture at 95 gals. an acre.

[18]Samples taken after the application.

curate enough considering the comparatively great errors in getting samples that are truly representative of the field application of fungicides.

The copper was calculated in terms of milligrams per 10 grams of dry leaves. Incidentally the green weight of most of the samples was determined, but variation occurred in conditions of transpiration at picking and in the length of time of drying before weighing, and the dry weight varied from 10.4 to 14.9 per cent of the green weight. The determinations of this copper index, with other pertinent data, are presented in Table 19.

An examination of this table shows that corresponding samples taken on the same date from duplicate plots differed as much as 11 and 17, 23 and 28, and 33 and 39, as to the copper index. (An index of from 3 to 23 is got by the conversion of Cook's results in this region (28, table 5).) However, there is in the two dust and two spray series a consistent increase of the copper with each new application and a decrease with the passage of time following an application. The decrease was especially marked for the dust series in the 3-day period from July 13 to 16, during which 2.4 inches of rain fell. The decrease between July 18 and 24 during which there was practically no rain, may be credited to leaf expansion and weathering due to other factors than rainfall. A consistently and decidedly higher copper index appears and persists for the two sprayed series after the second application, giving rise to the conclusion that sprayed copper adheres better than dusted copper.

The results of Table 19 are depicted graphically in Fig. 25. Here the broken lines represent the copper index for two dusted plots and the solid lines paralleling them represent two sprayed plots. Days are represented by alternate vertical lines of the cross-section background, designated as to dates at the bottom of the figure. The dates of the six applications are shown by the vertical solid lines. It is the angles in the copper-index lines that denote sampling. It will be noted that after July 16 the two dust lines (or the two spray lines) are closer together at any angles occurring on any date line, than are the dust lines to the spray lines.

It should be pointed out that in Table 19 a trace or more is indicated for most of the control samples. This approaches in smallness the proportion of 0.1 milligram to 10 grams dry ma-

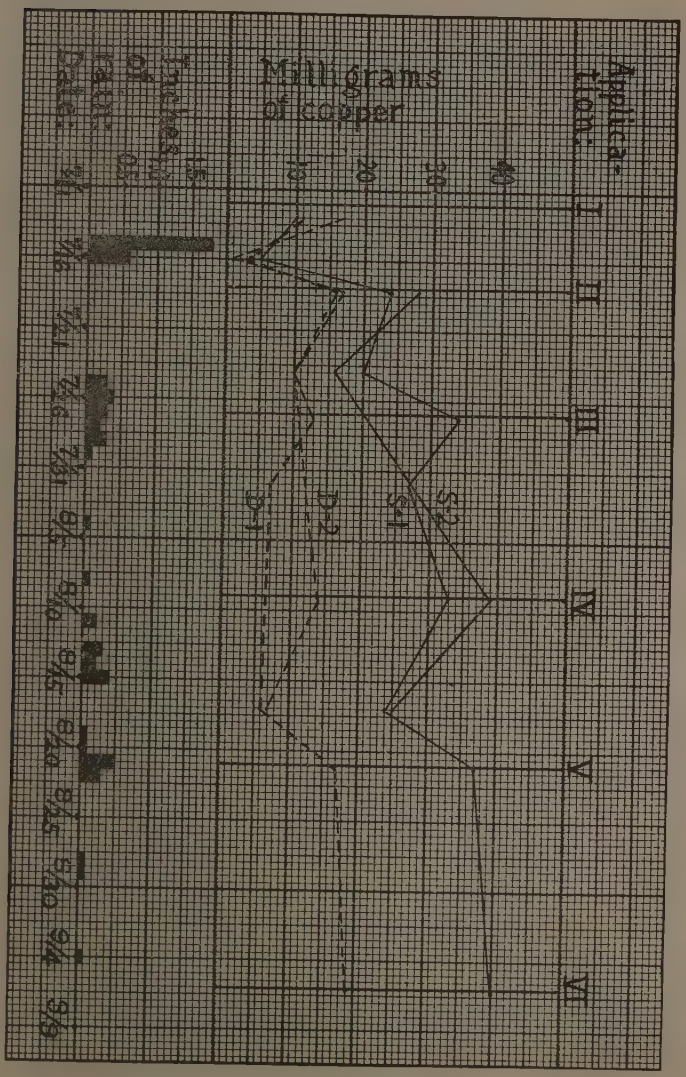

FIG. 25. Diagram showing results of copper analysis of samples collected at different dates in 1923. For full explanation see text, p. 276.

terial, or 10 parts per million. In Aroostook County Cook (27) has found as much as 69 parts per million in untreated potato leaves, as compared with 1 to 5 parts per million in the soil, as the result of absorption from the soil in the absence of all fungicides. Therefore at least a trace is to be expected. Where none is indicated in Table 19 for the later samplings, electrolysis was not completed because of the smallness of the amount as indicated by the color in the ammoniacal solution. Larger amounts of copper than a trace, given in Table 19 for the control samples, may be due in plot 0-1 to the absence of a buffer row between the sampled rows and the adjoining sprayed plot, and in plot 0-2 to drift from the applications made on the dusted plots adjoining on both sides.

It also should be pointed out that the so-called adherence may be involved with absorption of the copper by the leaves. Whether the copper recovered, after spraying, by a method of analysis which includes ashing the leaves is in part copper that has been absorbed by the leaves, is open to question (30, p. 228-233). Still less is known about this problem in relation to copper-lime dusting. Theoretically, at least, it seems possible that there may be more absorption from one than from the other and that absorbed copper may be more (or less) advantageous to the crop than adhering copper. Results got by Cook in this region show the amount of absorbed sprayed copper to be much smaller even than the amount occurring normally in unsprayed leaves (29, Table 9).

The adherence of copper in the 5-4-50 Bordeaux used in 1923 probably was somewhat better than if 5-5-50 Bordeaux had been used (28, p. 20; 22, p. 440).

Conclusions from Tests in Aroostook County

Briefly and very generally, the results of the four years' tests comparing copper-lime dust and Bordeaux mixture show that with the amounts of metallic copper equivalent, dust is practically as good for controlling late blight, is markedly inferior for controlling flea beetles and early blight, permits earlier maturing, and permits about the same yield production even with some prematuring. The question of hopperburn apparently is irrelevant to this region. Dust was considerably more expensive due to the cost of factory mixed materials. This takes into account the first three general advantages proposed on p. 268, leaving two more to be considered.

As to timeliness of applications, superiority of dust will depend somewhat upon the climate and weather. In our tests the recommendations of the manufacturing advocates of dust were followed and the dust applied on still, dewy mornings. This was not because any evidence had accumulated yet showing that dust was more effective when applied in that way, but it was because any drifting of dust onto nearby check and spray plots was to be avoided, and this necessitated dusting in quiet periods. Experience soon showed that quiet could be expected most often soon after sunrise, and when the air was quiet at this time it always proved to be clear and dewy. Even so, at one time six consecutive mornings were windy when we thought it was time for another application. In this region it is as difficult to find time for dusting in still, dewy conditions as it is for spraying in good fair-weather conditions. It is still an open question whether dusting is desirable under other conditions. Wallace (86, p. 90) has found that according to tests made on Aroostook Farm in 1924 and previously, the copper-lime dusts were more effective when applied soon after sunrise than when applied on dry foliage later in the day. He points out that this may be due to better control of the distribution of the dust in calm air, to better adherence to wet foliage, to less loss of lime through carbonation, to quicker formation of a better Bordeaux mixture in dew, and to less danger of washing off by rain before setting.

Although spraying is disagreeable to many, dusting is likewise disagreeable to some workers. There is some disadvantage in having to apply materials outside of the regular working hours, which many workers consider long enough already. A slight breeze sometimes carries the dust along with the machine so that some dust is inhaled. While this is reported (46) to be harmless even when containing an arsenical, it is disagreeable to some at least. In the course of working with a duster sometimes skin poisoning results, as experienced by the senior writer and as reported by Lutman (53).

SPRAYING TO KILL THE TOPS IN A SEASON OF LATE FALL FROSTS

In 1924 the tops were still generally disease-free in Green Mountain fields by the last half of September, the tubers were

still immature and easily bruised, and with the heavy foliage there threatened the necessity of the occurrence of more than one killing frost before digging could be done satisfactorily. Also, with a generous late sprinkling of late blight spots on the leaves there threatened also the danger of infection of the tubers before a killing frost occurred or of infection at the time of digging.

On August 15, 5-50 copper sulphate solution was applied to plots that had been sprayed three times previously in the standard way, and that had one or more late blight spots on each plant. No injury was apparent within ¾ hour and the next day only slight burning and some spotting on the upper leaves could be found as an effect. On the 16th, a 2½-50 solution of Watson's arsenoid (containing as an "active ingredient sodium arsenate not less than 80%") was applied twice. Some burning appeared within ½ hour, and part of the tops were killed. Another application several days later promised to finish the work, but this was done instead by a heavy frost on the morning of the 26th.

It would seem that copper sulphate should have been used at a greater concentration than 5 pounds to 50 gallons. Previous tests with 100-50 iron sulphate have been made here, but with the tops much younger that were killed (91, p. 43-46; 92, p. 51-52). This material was not so easy to get as copper sulphate or the arsenoid, which is an important factor in such an emergency.

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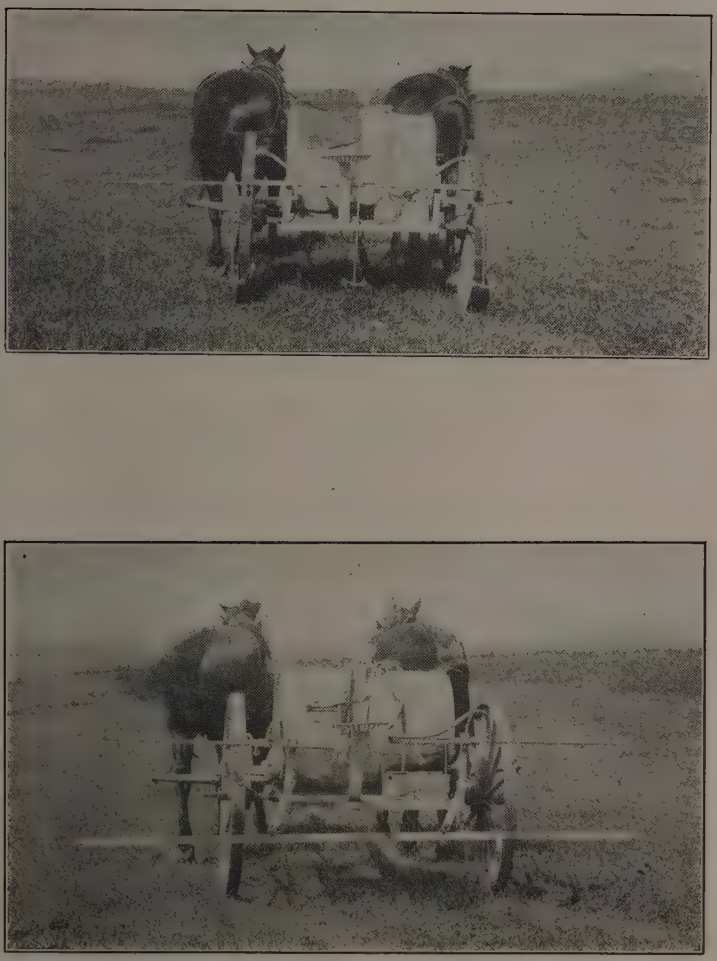

FIG. 26. Above, twelve-nozzle spray boom of the L. B. Smith type, with drop nozzles. Below, eight-nozzle spray boom with drag-bar. See Table 2 and p. 219 of text.

Fig. 27. Plant sprayed with Bordeaux mixture. Photographed on July 2, 1921. Compare with Fig. 28.

Fig. 28. Plant sprayed with Bordeaux mixture containing some commercial kerosene emulsion. Note incomplete spreading of the spray materials, comparing with Fig. 27.

Fig. 29. Part of spray boom bearing drop nozzle. Photographed in Green Mountain field on July 21, 1921. Such vine growth makes it difficult to get good distribution of so-called contact insecticides.

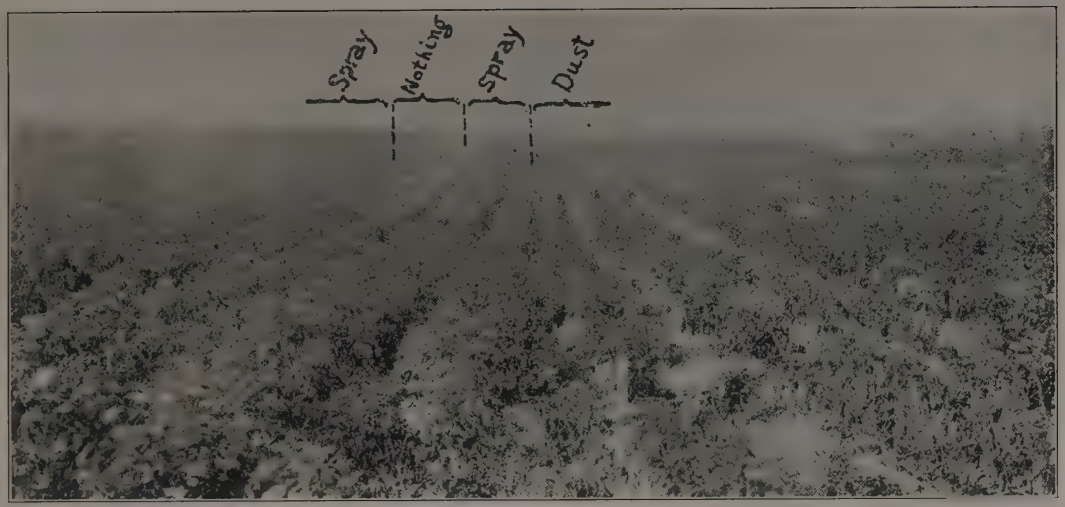

FIG. 30. Looking north on the Getchell farm test on September 9, 1922. The middle furrow separates the dusted section on the right from a 4-row sprayed section on the left. Further to the left is first a 4-row untreated section and then a sprayed section. The further ends of the untreated rows were sprayed. The dusted rows on the right, though dying earlier, yielded slightly better than the sprayed rows (see p. 224).

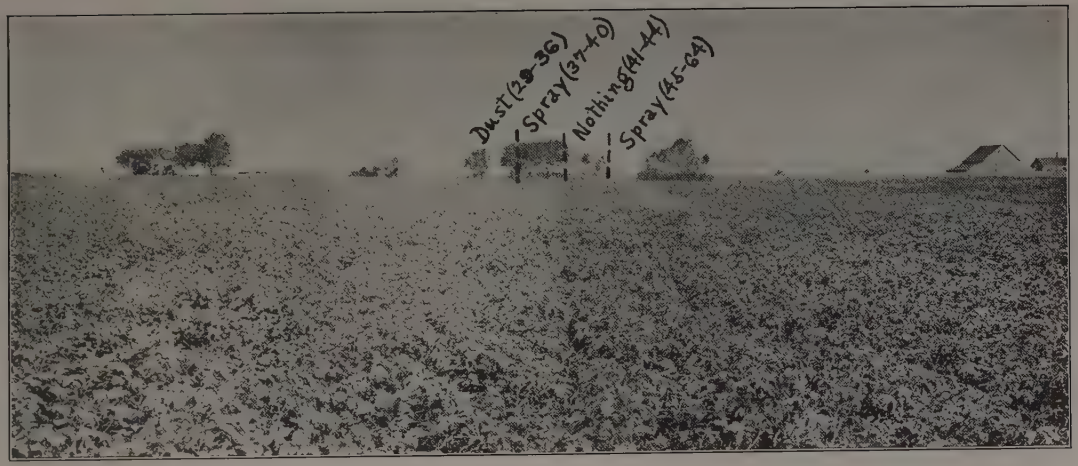

FIG. 31. Aroostook Farm early-planted test plot looking north, August 29, 1922. On the right is first an untreated section (Rows 41-44) and then sprayed sections (Rows 45-64). On the left is first a sprayed section (Rows 37-40) and then a dusted section (Rows 29-36). The untreated section was slightly brown at this time. The numbers refer to the rows in a section. See Fig. 32 for a later view.

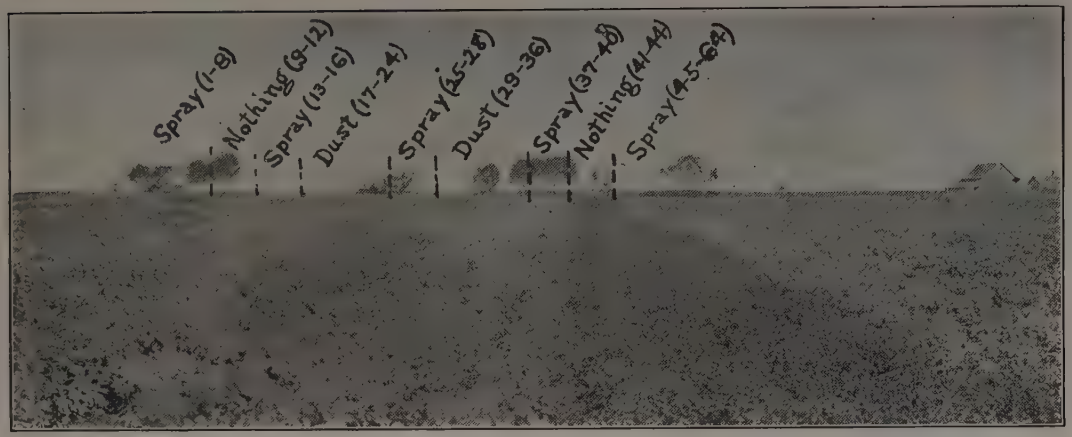

FIG. 32. Photograph taken September 7, 1922, from the same place as Fig. 31. The dusted sections were about as brown as the untreated had been on August 29, and the untreated section was much browner. The numbers indicate the rows in each section. For yields see Fig. 24 and Table IV.

FIG. 33. Leaves from unsprayed control plot of 1923. Photographed on September 1, 1923. Note absence of flea beetle injury and of blight, comparing with Figs. 31 and 32.

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No. 320. Influence of Ultra-violet Light on Nutrition in Poultry.
No. 321. Abstracts of Papers not Included in Bulletins, Finances, Meteorology, Index. 1924.
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Bulletin 327

STUDIES OF MILK SECRETION. XVI. PROGENY PERFORMANCE OF GUERNSEY SIRES' SONS. An important guide to success in constructive breeding. The material presented in this bulletin is a study of the average progeny performance for all Guernsey sires' sons where these sons have two or more Advanced Registry daughters. All records are corrected to the mature form production so that the average performance of these sons is directly comparable. The sons are tabulated under their sires and the average progeny performance of the sons of these sires is given for milk yield, butter-fat percentage and butter-fat.

The data are presented to show the variation in the sires' performance and that of his sons. The relation between the son's daughters' milk yields and the sire's daughters' milk yields. Butter-fat percentages and butter-fat are also tabled. The data show that a sire's progeny performance to some extent indicates what his son's probable progeny performance will be.

Bulletin 329

STUDIES IN MILK SECRETION. XVII. TRANSMITTING QUALITIES OF GUERNSEY SIRES FOR MILK YIELD, BUTTER-FAT PERCENTAGE AND BUTTER-FAT. The crux of the dairymen's breeding problem is the selection and maintenance of a bull transmitting high milk yield, butter-fat percentage and butter-fat. To intelligently make such a selection it is necessary to have certain information on the transmitting ability of the bulls within a given breed. Bulletin 329 furnishes this information in a study of the daughter's production in contrast to that of the dam for all Guernsey Advanced Registry sires having two or more daughters. Tables are presented showing the average daughter-dam difference in milk yield, butter-fat percentage and butter-fat for these bulls.